Original Article

Developing a model for prioritizing occupational risk prevention practices in industries: a Delphi study

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Abstract:

Background: Occupational accidents, injuries, and diseases remain critical health concerns. Designing and implementing checklists for occupational risk prevention are key strategies to mitigate these accidents and their adverse effects. However, due to the diverse nature of occupational hazards, these checklists tend to encompass a substantial number of prevention practices, making their full implementation challenging in terms of financial and human resources. Hence, this study aims to propose a prioritization model for these practices. By identifying and prioritizing the most crucial prevention practices, we can optimize resource allocation and enhance the overall effectiveness of occupational risk reduction.

Method: To develop a model, we initiated with the utilization of the Delphi method and conducted semi-structured interviews to identify the influencing factors in prioritizing occupational risk prevention practices. Through this process, we identified the type of hazard, the nature of prevention practices, cost considerations, and priority rankings as significant influential factors. Subsequently, we introduced a model designed to prioritize prevention practices in alignment with industry needs and the identified factors. This proposed model encompasses a comprehensive integration of the identified factors.

Result: The proposed model was designed and developed based on 146 prevention practices. The initial version of the software based on the developed model has been implemented and tested by users.

Conclusion: The developed model can be used as a decision support system for managers, offering a roadmap delineating the order of prevention practices according to set priorities. Through such strategic alignment, the model holds the potential to wield a profound impact on enhancing occupational safety and health within organizational contexts.

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Introduction

Occupational accidents, injuries, and diseases continue to pose significant challenges to public health.[1] According to the latest report published by the International Labor Organization (ILO), the annual toll of workers who lose their lives due to occupational accidents, injuries, or diseases surpasses 2.78 million,[2] which is the cause of 5 to 7% of deaths in industrialized countries.[3] In addition to fatal accidents, approximately 374 million non-fatal injuries occur annually, causing workers to be absent for more than four days.[2] Occupational accidents and injuries have significant negative consequences, leading to long-term disabilities, reduced work efficiency due to disability, early retirement, and even fatalities. These consequences impose substantial

economic costs on countries. The cost of these negative consequences is equivalent to 1.8 to 6% of GDP in different countries,[3] which is globally equivalent to 3.94% of world GDP, which is equivalent to 2.8 trillion US dollars.[2]

Various strategies have been implemented by countries and organizations to effectively reduce occupational accidents and mitigate their negative consequences. These strategies include: 1) Enacting laws and regulations aimed at minimizing occupational accidents. 2) Implementing mandatory programs for organizations and industries to address and prevent occupational accidents and their consequences. 3) Enhancing workers' knowledge and awareness about occupational accidents, their potential consequences, and effective solutions for prevention. 4) Offering incentives to encourage and promote safety practices in the workplace. 5) Providing occupational safety and health services to companies and organizations to foster a safe working environment. 6) Establishing networking platforms to facilitate the exchange of successful experiences and best practices between organizations, companies, and individuals, thereby improving overall working conditions.[3]

Due to the critical nature of the subject, numerous research studies have been conducted to address and reduce occupational accidents, as well as their detrimental consequences.[4-6] These studies can be broadly categorized into two main approaches: treatment and preventive interventions.[7] Preventive interventions aim to either modify the work environment or workers' behavior in ways that reduce the occurrence of occupational accidents or, in the event of an accident, mitigate its negative consequences.[7] These preventive interventions are further divided into three main categories: primary, secondary, and tertiary prevention interventions.[7] Primary preventive interventions are designed to establish conditions that prevent occupational accidents and injuries from happening in the first place. They focus on proactively creating a safe work environment and promoting safe work practices.[7] On the other hand, secondary and tertiary preventive interventions concentrate on the post-accident stages and aim to minimize the adverse consequences of an occupational accident or injury. These interventions involve prompt and effective responses to accidents, providing timely medical care and rehabilitation, and ensuring a smooth return to work for the affected individuals.[7] By implementing these various preventive interventions, we can significantly improve workplace safety and reduce the impact of occupational accidents, ultimately promoting the well-being of workers and organizations alike.[7]

The implementation of occupational risk prevention practices, structured as checklists, serves as a key intervention for promoting workplace safety and health.[8-11] Current research on occupational risk prevention checklists can be divided into two primary streams. The first focuses on identifying the crucial factors influencing the successful implementation of preventive interventions,[12-17] while the second emphasizes the systematic development of checklists tailored to occupational safety requirements.[8-11] Despite these advances, a notable gap persists in research. This gap underscores the necessity for a comprehensive approach that not only identifies key factors for checklist items but also informs their prioritization based on real-world needs and constraints. In other words, although numerous checklists have been developed to address diverse occupational hazards, their comprehensive execution is often hindered by the extensive volume of practices they encompass. This challenge is further intensified by the considerable financial, human, and equipment resources necessary for full implementation, emphasizing the need for prioritizing these practices based on industry-specific needs.

Addressing this gap, our study aims to achieve two core objectives. First, we seek to identify the key factors that influence the prioritization of occupational risk prevention practices, incorporating perspectives from managers who play a crucial role in implementing these measures. This objective aims to develop a foundational understanding that will guide the effective allocation of resources and emphasize the most essential safety practices.

Building upon the identified influential factors, our second objective is to propose a model that integrates these factors to prioritize checklist items, offering an optimized framework for safety and health practices. By advancing a systematic approach, our research contributes to evidence-based decision-making, enhancing occupational safety and supporting the well-being of workers across diverse industries.

Review of Methodological Approach

A study[15] was conducted to examine business practices, health, safety, and wellbeing initiatives, as well as measurement systems, to develop a comprehensive health, safety, and wellbeing strategy alongside an employee engagement framework that adds strategic value beyond standard practices. This exploratory mixed-methods study included eight semi-structured interviews and 95 survey responses from leaders in both private and public sectors and professionals in health, safety, wellbeing, and human

capital. Thematic analysis and exploratory factor analysis identified a seven-factor strategy framework for health, safety, and wellbeing that integrates key elements such as resilience engineering, wellbeing, health and safety management, employee engagement, risk management, and corporate governance. The final framework provides empirical evidence supporting a suitable model for organizations to enhance both individual and organizational performance.

A recent study[16] compares OHS regulatory standards in China and the European Union (EU), aiming to pinpoint gaps or weaknesses within the Chinese framework. The analysis includes a broad overview of OHS conditions in both regions, using various databases to evaluate socio-economic factors, accident rates, and the structure of OHS regulations. Since 1989, the EU has implemented an extensive, cohesive regulatory framework for OHS, which has contributed to its reduced accident rates and serves as a potential benchmark for other regions. In contrast, China's OHS legislation is complex, consisting of over 280 regulations that often overlap or repeat content. Unlike the EU's well-established framework, China's OHS laws remain under development, with major regulatory milestones only achieved within the last decade.

The research[17] explores critical elements in the implementation of organizational-level occupational health and safety interventions, providing steps to guide their successful execution. These steps are demonstrated through evidence-based best practices documented over the past decade, which systematically evaluate and detail the implementation process in published studies. The steps introduced in this research are 1) Defining the problem, 2) Analyzing resources and support, 3) Clarifying the goals and objectives 4) Searching for previous effective interventions, 5) Clarifying the intervention, 6) Promoting team building and empowerment, 7) Establishing an organizational infrastructure, 8) Undertaking initial implementation and further development, 9) Promoting innovation, and 10) Achieving sustainability and integration in standard procedures.

Authors in[8] developed a comprehensive evaluation system for the prevention and control of occupational hazards in the iron and steel industry. The system, based on extensive literature review, personal interviews, and Delphi expert consultations, utilized an improved analytical hierarchy process fuzzy comprehensive evaluation model. It established a three-level index system covering various aspects of occupational hazards. The weight coefficients and expert authority coefficients for the dimensions were determined, and the questionnaire's recovery and effective rates were reported. The consistency factors and reliability of the evaluation index system were also assessed, demonstrating its robustness. Additionally, factor analysis was conducted, extracting four common factors with a cumulative variance of 63.1%. The study concluded that the proposed evaluation system is comprehensive and reasonable, providing a potential strategic tool for scientific evaluation of occupational hazards in the iron and steel industry.

The Practical and evidence-driven recommendations for safeguarding American workers from heat stress in their occupational settings was formulated in.[9] The guidelines were tailored for use by safety managers, industrial hygienists, and employers responsible for implementing heat safety protocols. An interdisciplinary roundtable comprising 51 experts was convened to conduct a comprehensive review of current data and identify gaps in knowledge across eight key heat safety areas: heat hygiene, hydration, heat acclimatization, environmental monitoring, physiological monitoring, body cooling, textiles and personal protective gear, and emergency action plan implementation. Using the Delphi method, consensus-based recommendations were developed for each topic, taking into account scientific evidence, feasibility, and clarity. The resulting document presents 40 heat safety recommendations spanning all eight areas, aiming to assist organizations and employers in devising effective heat safety plans for their workplaces.

The study[10] aimed to improve the occupational safety and health (OSH) environment in Spain by comparing it with Sweden, a country known for its low rate of occupational accidents in Europe. The research, which involved a panel of seven experts, utilized the Delphi method to assess 14 key differences between Swedish and Spanish companies, with a focus on various OSH indicators such as socio-demographic, economic, and employment factors. The study aimed to identify the contributions of these factors to the occurrence and severity of occupational accidents and proposed tailored risk prevention practices for the Spanish industry. The proposed solutions targeted stakeholders including employers, safety managers, external prevention services, safety deputies, and Labor Inspectorates, with the goal of enabling decision-makers to implement impactful preventive measures. Overall, the study holds promise for enhancing occupational safety and health conditions in Spain by leveraging insights from a country with a strong OSH record, such as Sweden

In another study,[11] the Delphi method was employed to develop dimensions and safety-related items specific to hotels. The safety atmosphere in hotels was assessed

through a researcher-made questionnaire. The data collection process garnered responses from 432 valid questionnaires. Utilizing both exploratory factor analysis and confirmatory factor analysis, the study identified five distinct dimensions related to hotel safety. These dimensions are as follows: Psychology, Organization, Training, Behavior, Environment. By employing these dimensions, the study provides valuable insights into the various aspects of hotel safety and contributes to a more comprehensive understanding of creating a secure and safe environment for guests and staff.

Authors in a research study[12] propose an innovative three-step approach for conducting occupational safety and health risk assessment in Nuclear Power Plant (NPP) construction projects. The first step involves the identification of occupational safety and health risks using the brainstorming technique, classifying the risks into four categories: behavior risk, material, equipment, and facility risk, environment risk, and management risk. The second step entails the establishment of an Occupational Health, Safety, and Environment (OHSE) risk assessment index system through the Delphi method, creating 16 specific risk assessment indexes based on the categories defined in Step 1. The final step involves the development of a mathematical model for the approach by integrating Set Pair Analysis (SPA), Trapezoidal Fuzzy Number (TPFN), and Set-Valued Statistics (SVS). This model aims to provide a comprehensive and robust framework to assess and address the complex risks associated with NPP construction projects effectively, ultimately contributing to the promotion of a safer work environment and helping mitigate occupational hazards in the nuclear power industry.

Also in another study,[13] the identification and prioritization of occupational stressors among firefighters were accomplished using the Fuzzy Delphi Method (FDM) and Fuzzy Analytical Hierarchy Process (FAHP). The study involved 40 experts with extensive knowledge and experience in the field. A total of 27 occupational stressors were extracted and categorized into four main dimensions: 1) Interpersonal dimension; 2) Operations (working conditions) dimension; 3) Personal dimension; 4) Managerial and organizational dimension. Interestingly, the results indicated that the fourth dimension, i.e., managerial and organizational factors, emerged as the primary source of job stressors for firefighters. As a consequence, decision-makers should prioritize strategies aimed at reducing stressors in this specific dimension. By utilizing the FDM and FAHP methodologies, this study provides valuable insights into the complex nature of stressors affecting firefighters. The findings can be instrumental in formulating targeted interventions and support mechanisms to alleviate job-related stress and enhance the overall well-being and performance of these dedicated professionals.

In a study,[14] scholars introduce a valuable tool designed to assess occupational safety and health activities in the municipalities of Iranian megacities. This comprehensive tool has been developed based on a diverse collection of 13 categories of indicators. The findings of the study reveal that the "Fire and emergency response" category holds the utmost significance and should be the top priority for municipalities to address. This emphasizes the critical importance of preparedness and effective emergency response measures in ensuring the safety and well-being of the workforce. The development of the tool involved conducting Delphi rounds with a panel of 12 experts, comprising 4 academic experts and 8 practitioners from municipalities. The involvement of both academic and practical experts ensures a well-rounded approach to creating an effective evaluation tool that considers real-world challenges and theoretical insights. By implementing this assessment tool, municipalities can systematically evaluate their occupational safety and health activities, identify areas of improvement, and allocate resources strategically to foster a safer working environment for employees. This study significantly contributes to enhancing workplace safety practices within Iranian megacities, promoting better occupational health outcomes for municipal workers.

Methods

This paper addresses two research questions, leading to the division of the method section into two parts. In the first section, the Delphi method and semi-structured interviews will be used to determine the influencing factors on prioritizing occupational risk prevention practices. Experts' opinions will be gathered through the Delphi method to reach a consensus, while semi-structured interviews will provide insights from industry professionals and practitioners.

The second section will introduce a model for prioritizing prevention practices based on industry or factory needs and the identified factors. This model aims to offer a structured approach to tailor risk prevention strategies to meet the unique requirements and challenges faced by different industries or factories. By combining both methods and presenting a comprehensive model, this paper seeks to enhance occupational risk prevention practices and aid decision-makers in making informed choices to mitigate workplace risks effectively.

Goal 1) *Determining the influencing factors on occupational risk prevention practices*

As mentioned in the introduction section, multiple checklists have been devised to mitigate occupational accidents and their adverse impacts in industries, with each checklist encompassing various occupational risk prevention practices. The initial stage of developing our model involves identifying the influential factors that drive the prioritization of prevention practices.

To ascertain these factors, researchers conducted semi-structured interviews with managers from diverse factories. The questions of the semi-structured interview are in the **appendix A**. Through these interviews, the researchers extracted the most critical influencing elements that affect the implementation of prevention practices. These factors include the type of occupational accident prevention, type of hazard, priority, and cost. For ease of reference, these features are collectively referred to as "*Tag*."

In the subsequent step, we aim to establish the valid range and assign appropriate values to the tags for prevention practices. To accomplish this, we have employed the Delphi technique. In the following section, we will provide a comprehensive explanation of the tags and delve into the details of the Delphi method utilized in this study.

Defining Tags

Tag1: Type of hazard (Type of Hazard tag):

As previously mentioned, a plethora of published checklists are available for assessing hazardous workplaces or evaluating the unsafe behavior of workers in diverse settings.[18-20] From the comprehensive list of occupational health and safety checklists, the final checklist was carefully chosen based on specific criteria. The selected checklist is designed explicitly for industries in developing countries and encompasses all essential aspects of occupational safety and health. Notably, it includes occupational risk prevention practices applicable to all levels, ranging from the workforce to managerial positions. This ensures a comprehensive and inclusive approach to address safety concerns across different occupational roles in the industry.

Based on the provided criteria, the "ILO Program for Occupational Safety and Health and Environment for the Caribbean" was selected. This program has been provided by the ILO and is available on the ILO website[20] and assesses occupational safety and health from 11 different perspectives. Each checklist within the program contains a different number of occupational risk prevention practices (**Error! Reference source not found.**).

The primary objectives of checklist[20] are as follows: 1. Establishing guidelines for developing industry-specific occupational safety and health strategies. 2. Assessing and identifying occupational safety and health risks and hazards within industries. 3. Providing comprehensive guidelines for the implementation and development of Occupational Safety and Health Management Systems. 4. Supporting academic occupational safety and health training programs to ensure effective delivery and impact. These goals demonstrate the checklist's wide-ranging utility, aiming to enhance workplace safety, promote effective risk

Table 1."ILO Program for Occupational Safety and Health and Environment for the Caribbean" checklists (20)

#	Name (Category of prevention practice)	# prevention practices
1	Checklist for Chemicals	16
2	Checklist for Electrical	12
3	Checklist for Fire Safety	30
4	Checklist for General Workplace Conditions	14
5	Checklist for Lighting	10
6	Checklist for Machine Guarding	9
7	Checklist for Noise	13
8	Checklist for Policy and Implementation	17
9	Checklist for Temperature and Ventilation	15
10	Checklist for Welfare Facilities	24
11	Checklist for Workstation Design	10

management, and foster a culture of occupational safety and health within industries.

In the checklist, each prevention practice is accompanied by its corresponding hazard category, providing valuable information on potential risks. As a result, the valid range #Type of Hazard and the default value of #Type of Hazard for each prevention practice are clearly specified, offering a structured approach to understanding and addressing specific hazards associated with the practices.

Tag2: Type of occupational accident preventions (Type of Intervention tag):

Occupational accident interventions are divided into three main categories: 1) behavioral interventions,[21-23] 2) environmental interventions,[24-26] and 3) organizational interventions.[27-29] Interventions can cover one, two or all three categories. For example, an intervention can be both an environmental intervention and an organizational intervention. This classification is denoted by the #Type of Intervention tag. The valid range for the #Type of Intervention tag comprises Behavioral-Intervention, Environmental-Intervention, Organizational-Intervention, or any combination thereof.

Tag3: Priority of prevention practice (Priority tag)

The priority of prevention practices holds significant importance for managers when selecting which practices to implement. In the conducted semi-structured interviews with managers, the priority of each prevention practice was established based on their responses to the following questions: 1) How effective is the prevention practice in preventing occupational accidents and injuries? and 2) When an accident occurs, how effective is the prevention practice in reducing its negative consequences?

To represent the priority of each prevention practice, the #Priority tag is utilized. The valid range for this tag comprises High-Priority or Low-Priority, based on the aforementioned answers. The concept of occupational safety is intricately linked to the assigned priorities. It revolves around identifying factors that may lead to injuries or accidents in the workplace and making concerted efforts to eliminate or mitigate the impact of these factors. By doing so, the occurrence of occupational accidents can be significantly reduced.[30-31]

Tag4: Cost of prevention practice (Cost tag)

While the priority of a prevention practice is undoubtedly important, decision-making can be better guided by considering both the priority and the associated cost of each practice. For interventions listed in the checklists, the estimated implementation cost holds significant weight for decision-makers when choosing suitable measures. In health, as in other domains, the cost-benefit aspect plays a pivotal role in making informed choices.[32-35] By taking both priority and cost into account, decision-makers can optimize resource allocation and ensure that effective prevention practices are selected while considering the financial feasibility of their implementation.

In the conducted semi-structured interviews with managers, the cost of each prevention practice is estimated based on five criteria. Firstly, the financial investment required for implementing the prevention practice is considered. Secondly, the time it takes to execute the prevention practice is evaluated. Additionally, the extent of environmental changes necessary for environmental interventions, the level of organizational adjustments required for organizational interventions, and the changes needed in workers' duties for behavioral interventions are all taken into account. Lastly, the degree of willingness or readiness of industries to adopt the prevention practice is considered.

To represent the cost of each prevention practice, the #Cost tag is utilized. The valid range for this tag comprises Low-Cost or Expensive, based on the above considerations.

Finally, for each prevention practice, the following structure will be extracted (**Error! Reference source not found.**).

Assign tag to occupational risk prevention practice (Delphi Method)

Considering that out of the 4 tags introduced, the value of the #Type of Hazard tag for each of the prevention practices is determined based on the checklist. Therefore, values for the other three tags are required for each prevention practice. Given that #Type of Intervention, #Priority, and #Cost are qualitative tags, qualitative methods are essential for their determination. One of the most significant qualitative approaches is systemic methods. These methods incorporate both available data and the valuable insights of experts to arrive at the final outcome.[36]

The Delphi method stands out as an efficient, inclusive, and structured technique within the qualitative method category.[37] These characteristics make it an excellent tool for enhancing decision-making processes[38] and improving result quality, particularly in situations where data availability is limited.[39] Consequently, the Delphi method has found extensive application across various fields, including health,[38, 40] social policy, and tourism.[40]

In this method, a panel of experts engages in a group communication process to collectively evaluate evidence and reach a consensus.[37] By harnessing the wisdom and expertise of these specialists, the Delphi method empowers research and decision-making endeavors,

Table 2. The defined tags for prevention practice.

Tag	Values	Selectin Mode
#Type of Hazard	It is determined based on the published checklist: Chemicals Electrical Fire Safety General Workplace Conditions Lighting Machine Guarding Noise Policy and Implementation Temperature and Ventilation Workstation Design Welfare Facilities	Single-Selection
#Type of Intervention	Behavioral-Interventions Environmental-Interventions Organizational-Interventions	Multiple-Selecting
#Priority	High-Priority Low-Priority	Single-Selection
#Cost	Low-Cost Expensive	Single-Selection

ultimately contributing to more robust and well-informed outcomes.

The Delphi method is used to determine the type of occupational accident prevention (#Type of Intervention), priority (#Priority), and cost (#Cost) of each prevention practice. The process involved a structured, single-round approach to reach a consensus among experts. Initially, the experts were asked to determine the type of intervention of each prevention practice into one or more of the following categories: behavioral, environmental, or organizational. They were allowed to select multiple categories, acknowledging that some interventions might have overlapping aspects. This classification was conducted in a single round, with each expert independently assigning categories.

After the categorization phase, the experts were asked to prioritize the prevention practices by classifying them as either high or low priority, based on the definition given in the previous section. This step also involved a single round. Individual judgments were collected for each practice. Finally, the experts evaluated the cost of implementing each prevention practice by categorizing it as either high cost or low cost. The cost assessment followed the same single-round process, with experts providing their cost estimations based on the definition given in the previous section. An example of the output for a prevention practice is shown in Table 3.

Experts

In Iran, several organizations are tasked with delivering occupational safety and health services and training. Among them, the Fire and Safety Services Organization of Iranian Municipalities holds significant importance. As this study centers around this particular organization, the Checklist for Welfare Facilities, not falling within the scope of its services, was excluded from the final checklists. Consequently, 10 checklists comprising a total of 146 prevention practices have been retained for analysis and examination. This study was conducted in the city of Mashhad. Accordingly, experts have been selected among the employees of the Mashhad Fire and Safety Services Organization.

Experts were carefully selected based on their extensive experience in operational safety and health practices within the Fire and Safety Services Organization. The selected individuals have a minimum of 10 years of experience, particularly in the training and operations departments, where they have consistently interacted with various industries. These departments regularly assess industrial safety challenges, giving the experts first-hand exposure to the practical safety concerns across multiple sectors, including manufacturing, construction, and public service industries. Their deep involvement in safety evaluations and the development of training programs ensures that they possess a comprehensive understanding of occupational safety protocols relevant to a wide array of industrial contexts.

Moreover, to ensure that the selected experts collectively cover the key aspects of occupational safety across industries, the study considered individuals with diverse roles within these departments. This includes specialists in risk assessment, emergency response, safety training, and incident analysis, all of whom bring specialized knowledge essential for occupational safety across various sectors. As a result, the expert panel is well-equipped to provide a broad perspective on safety

practices, enhancing the generalizability of the findings to industries beyond just fire and safety operations. Demographic and job information of the experts is summarized in Table 4.

The decision-making process of the experts in the Delphi method was guided by their extensive experience in operational safety and health practices, as well as their direct interactions with various industries. Furthermore, through semi-structured interviews, managers from diverse factories leveraged their practical knowledge gained from assessing and implementing safety programs. As a result, the questions posed during the interviews served as guidelines for understanding the underlying factors that influenced the experts' decisions in the Delphi method, ensuring a comprehensive approach to tagging prevention practices.

Given that 5 experts participated, 5 records were recorded for each prevention practice. The result obtained for each prevention practice after performing the Delphi method is shown in Table 5.

The summary of experts' votes on the above prevention practice is shown in Table 6Error! Reference source not found.. The number in parentheses indicates the number of votes cast for the prevention practice.

Table 6 illustrates that 4 experts have categorized this prevention practice as an organizational intervention, while 3 experts have placed it under behavioral intervention, and 1 expert has assigned it to environmental intervention. It is important to highlight that a prevention practice can be included in multiple types of interventions, potentially falling under two or even three categories. Furthermore, this prevention practice has been identified as both expensive and high priority. All experts concurred that the prevention practice incurred significant costs, whereas only one expert considered it to have low priority.

Consensus was defined as 60% or more agreement among experts on the assigned tags (at least three of the five experts). For example, to classify a prevention practice as expensive, at least three experts must agree on its cost implications. These comprehensive assessments by the panel of experts provide valuable insights into the multi-faceted nature of prevention practices, encompassing various interventions and factors that contribute to their prioritization.

Figure 1 shows the process followed to achieve the first goal.

Goal 2) *Prevention practices Prioritization Model*

In the previous section, we focused on addressing the first objective. In this section, our aim is to fulfill the second objective: "introducing a new model to propose an optimal set of practices aimed at enhancing the safety and occupational health atmosphere within the factory or industry."

Two processes have been introduced to create the model. In the first process, suitable prevention practices are determined based on the industry/factory's conditions from among the 146 available prevention practices (Selection Process). Then the priority of each selected prevention practice must be determined (Prioritization Process). #Type of Hazard and #Type of Intervention will be used for the first process and #Priority and #Cost will be used for the second process.

Table 3. The information recorded for a prevention practice by an expert. $Expert_k$ is *k*th expert, $Checklist_i$ is *i*th checklist and $practice_{ij}$ is *i*th prevention practice on the *j*th checklist

Expert	Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Expert_k$	$Checklist_i$	$practice_{ij}$	☑Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive

Table 4. Demographic and job information of experts in the Delphi method.

Expert	Position	Gender	Academic degree	Age	Work Experience
$Expert_1$	Director of Education Department	Male	Doctorate	41	15 years
$Expert_2$	Director of Industrial Education	Male	Master	52	24 years
$Expert_3$	Firefighter/industry training instructor	Male	Bachelor	33	10 years
$Expert_4$	Firefighter/industry training instructor	Male	Doctorate	36	12 years
$Expert_5$	Firefighter/industry training instructor	Male	Master	46	23 years
Average				42	17 years

Table 5: Delphi method output for a prevention practice. $Expert_k$ is *k*th expert, $Checklist_i$ is *i*th checklist and $practice_{ij}$ is *i*th prevention practice on the *j*th checklist

Expert	Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Expert_1$	$Checklist_i$	$Practice_{ij}$	☑Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive
$Expert_2$	$Checklist_i$	$Practice_{ij}$	☑Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○Low-Cost ● Expensive
$Expert_3$	$Checklist_i$	$Practice_{ij}$	☐Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive
$Expert_4$	$Checklist_i$	$Practice_{ij}$	☑Behavioral-Intervention ☐Environmental-Intervention ☐Organizational-Intervention	○ High-Priority ●Low-Priority	○ Low-Cost ● Expensive
$Expert_5$	$Checklist_i$	$Practice_{ij}$	☐Behavioral-Intervention ☑Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive

Table 6: The summary of experts' votes on the prevention practice. The numbers in parentheses are the number of votes. $Checklist_i$ is *i*th checklist and $practice_{ij}$ is *i*th prevention practice on the *j*th checklist

Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Checklist_i$	$Practice_{ij}$	Behavioral-Intervention (3) Environmental-Intervention (1) Organizational-Intervention(4)	High-Priority (4) Low-Priority (1)	Low-Cost (0) Expensive (5)

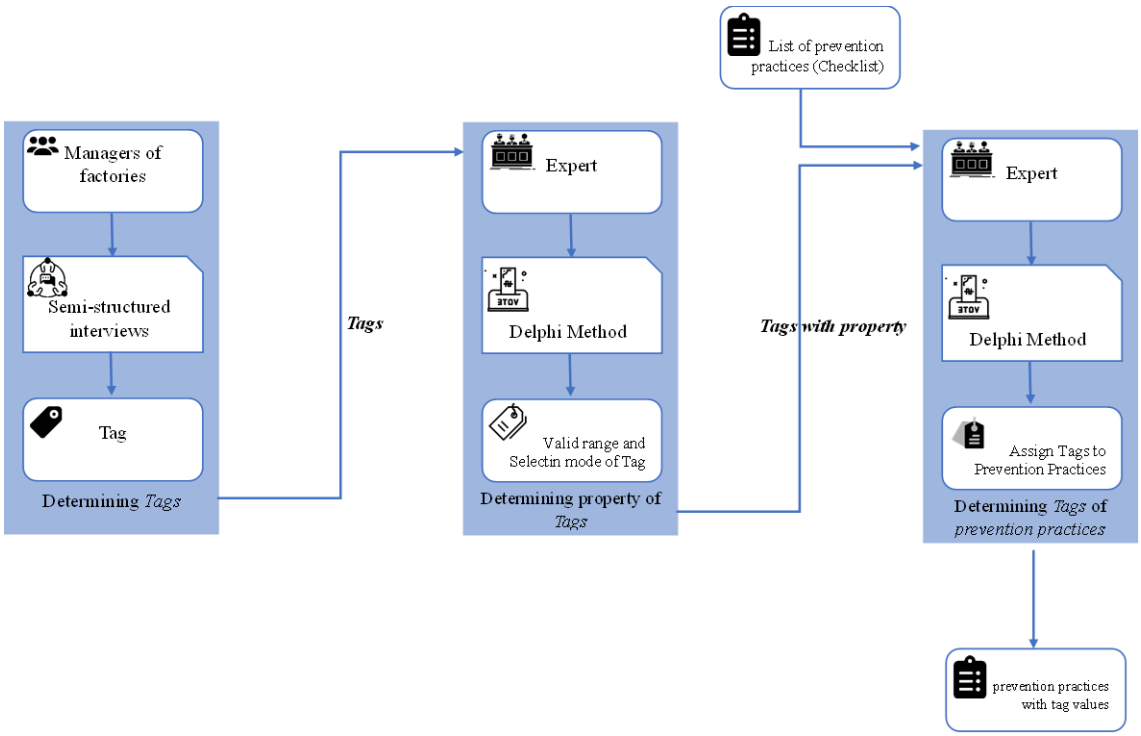

Figure 1: The process of identifying factors affecting the prioritization of occupational risk prevention measures.

Proposed Selection Process

Before introducing the selection process, several relevant terms are defined:

- **Checklist:** A set containing 10 selected checklists (**Error! Reference source not found.**).
- **Category:** The set includes three types of intervention

Category = {Behavioral_Intervention, Environmental_Intervention, Organizational_Intervention}

- **Practice:** A vector containing 6 elements. prevention practice = <ChceckListName, #Beh, #Env, #Org, IsCost, HasPrio>
  - ChceckListName ∈ **Checklist**
  - #Beh: Number of experts who have placed prevention practice in *Behavioral_Intervention*
  - #Env: Number of experts who have placed prevention practice in *Environmental_Intervention*
  - #Org: Number of experts who have placed prevention practice in *Organizational_Intervention*
  - IsCost: prevention practice is expensive
  - HighPrio: prevention practice is high Priority

- **Practice Set:** A set of practices that are in checklists.

The proposed Selection process has 2 input parameters and 1 output parameter (**Pseudocode 1**)

- Checklists (Input parameter): The managers of each factory can choose any number of 10 checklists based on their needs.
- Threshold(**Category**) (Input parameter): This parameter regulates the number of output practices. This parameter determines the minimum number of votes given to a practice in **Category** to be included in the output practices. This parameter is also determined based on the needs of the factory/industry.

This parameter is a vector that has 3 elements. The value for each element can be in the range of 0 to 5.

Threshold(**Category**) = <Min_Beh, Min_Env, Min_Org >

Min_Beh,Min_Env, and Min_Org are the minimum number of experts who have placed prevention practice in *Behavioral_category*, *Environmental_category* and *Organizational_category* ,respectively.

- ReturnPractices (Output parameter): The practices selected based on the input parameters is placed in this parameter and is returned as the output
- In the first step of the proposed selection process (Pseudocode 1), all prevention practices belonging to the selected checklists by the factory managers (**Checklists** parameter) are extracted. In the step 2, from the selected prevention practices in step 1, those are selected that have received the minimum number of votes specified by the managers (Threshold(**Category**) parameter). In the last step, the remaining practices are returned as output (**ReturPractices** parameter).
- *Proposed Prioritization Process*
- In this process, it should be specified which of the prevention practices resulted from the Selection Process *should* have a higher priority to be performed. To conduct the Prioritization Process, a simple cost-benefit model based on the values of #Cost and #Priority tags for each prevention practice is devised, drawing inspiration from Eisenhower's Urgent/Important Principle.[41] The model is presented in Figure 2.

Input

$$\text{Checklists} \subset \boldsymbol{Checklist}$$
$$\text{Threshold}(\textbf{Category})$$

Output

$$\text{ReturnPractices} \subset \textbf{PracticeSet}$$

Mechanism:

Step 1: $\text{Initial}_{\text{Practices}} = \cup_{\text{Practice}Set}\ item.\text{ChceckListName} \in \text{Checklists}$

Step 2: foreach Practice in $\text{Initial}_{\text{Practices}}$

If ((Practice.#Beh ≥ Threshold.#Beh) AND (Practice.#Env ≥ Threshold.#Env) AND (Practice.#Org ≥ Threshold.#Org))

$$\text{ReturnPractices} = \text{ReturnPractices} \cup \text{Practice}$$

Step 3: return ReturnPractices

Pseudocode 1. Proposed process for selection process.

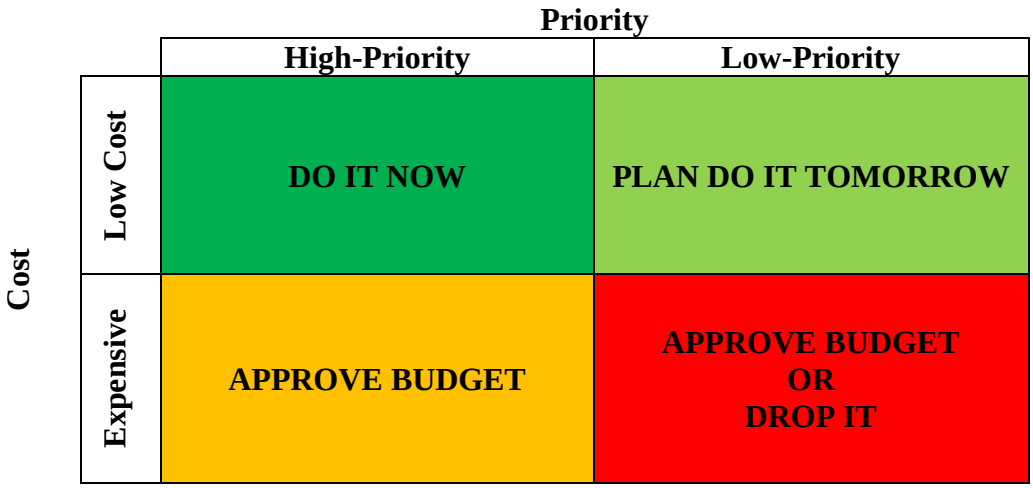

Figure 2: Cost-benefit model.

The prevention practices resulted from Selection process are placed in one of the above cells.

DO IT NOW: The prevention practices that are placed in this cell can be done at a low cost, but will have a significant impact on the safety of the factory/industry. Therefore, these prevention practices have the highest priority to perform.

PLAN DO IT TOMORROW: The prevention practices that are placed in this cell do not have as much effect on safety as the previous cell. Because cost is an important factor in decision making, this cell is a secondary priority.

APPROVE BUDGET: The prevention practices in this cell have the same impact on safety as the DO IT NOW cell, but their implementation requires budget approval. Occupational safety officers in the factories should do their best to get managers to agree to do the prevention practices in this cell.

APPROVE BUDGET OR **DROP IT**: The prevention practices in this cell have the lowest priority. If a factory/industry can plan to do the prevention practices in this cell, occupational safety in the factory/industry would be ideal. But if it has financial limitations, it can discard the prevention practices in this cell.

Using the proposed cost-benefit model, the Selection process in Pseudocode 1 can be completed as follows (Pseudocode 2):

In order to prioritize the prevention practice, Prioritization step, has been added to the proposed SelectionProcess (Pseudocode 2). In this step (step 3), the prevention practices selected in the step 2 are sorted according to the cost-benefit model. In other words, the prevention practices in **DO IT NOW** cell have the highest priority and the prevention practices in **APPROVE BUDGET** OR **DROP IT** cell the lowest priority to perform.

Given that there may be more than one prevention practice in each cell, a criterion for intracellular sorting needs to be defined. For this purpose, $\mathrm{Threshold}(\mathbf{Category})$ is used. First, the prevention practices are sorted based on cost-benefit model. Then the prevention practices in each cell are sorted based on ordered $\mathrm{Threshold}(\mathbf{Category})$.

An example is provided in order to better understand the proposed model.

Example1) Suppose the managers of a factory determines the following $\mathrm{Threshold}(\mathbf{Category})$ based on their factory conditions as follows:

$$\mathrm{Threshold}(\mathbf{Category}) = \langle \mathrm{Threshold.\#Beh} = 4\,, \mathrm{Threshold.\#Env} = 0\,, \mathrm{Threshold.\#Org} = 2 \rangle$$

According to the above vector, prevention practices are selected that have received at least 4 votes in *Behavioral_Intervention* and 2 votes in *Organizational_Intervention* and the number of votes given to the *Environmental_Intervention* is not important for the factory manager, so he/she has set a value of zero for it. Based on the above vector, behavioral interventions have the highest value, it means that occupational accident analyzes of factory have shown that unsafe behaviors are the most important source of occupational accidents. Therefore, managers tend to prioritize interventions that have the highest impact on unsafe behaviors. $\mathrm{Threshold.\#Env} = 0$ means that according to the managers' view, all environmental safety considerations are done in the factory and interventions in this category have the lowest priority.

Selected prevention practices can be as follows:

Input

$$\text{Checklists} \subset \boldsymbol{Checklist}$$
$$\text{Threshold}(\textbf{Category})$$

Output

$$\text{ReturnPractices} \subset \textbf{ItemSet}$$

Mechanism:

Step 1: $\text{Initial}_{\text{Practices}} = \bigcup_{PracticeSet} Practice.\text{ChceckListName} \in \text{Checklists}$

Step 2: foreach Practice in $\text{Initial}_{\text{Practices}}$

If ((Practice.#Beh ≥ Threshold.#Beh) AND (Practice.#Env ≥ Threshold.#Env) AND(Practice.#Org ≥ Threshold.#Org))

$$\text{ReturnPractices} = \text{ReturnPractices} \cup \text{Practice}$$

Step 3: ReturnPractices = OrderBy_CostBenefitTable (ReturnIPractices)

Tehn OrderBy_OrderedThreshold(ReturnPractices)

Step 4: return ReturnPractices

Pseudocode 2: Proposed selection of selection process

Figure 3.A shows a list of prevention practices selected based on $\text{Threshold}(\textbf{Category})$ conditions. It is assumed that only 10 prevention practices match the vector entered by the manager. Given that *Behavioral_Intervention* has the highest value ($\text{Threshold.\#Beh} = 4$) in $\text{Threshold}(\textbf{Category})$, the prevention practices are sorted first based on this attribute (Figure 3.B). The values of the #Beh column are bold in Figure 3.B, indicating that the prevention practices have been sorted solely based on this column thus far. According to the OrderedThreshold in the third step, the results in Figure 3.B are sorted based on *Organizational_Intervention* ($\text{Threshold.\#Org} = 2$). The result is shown in Figure 3.C. The values of the #Beh and #Org columns are bold in Figure 3.C, signifying that the prevention practices have been sorted only based on these columns thus far. It is important to note that sorting based on the #Org column is conducted in a manner that does not violate the sorting based on the #Beh column. In other words, prevention practices with equal #Beh values are grouped together, and each group is sorted separately. In Figure 3.C, prevention practices with #Beh values of 5 are sorted based on the values of the #Org column first, followed by those with #Beh values of 4. In the final step, sorting is done based on *Environmental_Intervention*, the results of which are shown in Figure 3.D. The principles outlined in the previous steps also apply to this step.

Figure 4 shows the process followed to achieve the second goal.

Results

By implementing the Delphi method with the participation of 5 experts, the values for the 3 tags—#TypeOfIntervention, #Priority, #Cost —were determined for all 146 prevention practices selected in this study. Due to the extensive number of prevention practices, only the results for the first 3 preventive measures of the chemical checklist are presented in the appendix B. The values of each tag for prevention practices are accessible to users through developed software. This section will discuss the general results related to the Delphi method.

The analysis of the 10 workplace checklists revealed diverse patterns. The prevalence of behavioral interventions varied significantly across the checklists. The Machine Guarding checklist had the highest proportion of behavioral interventions, with 56% of items falling under this category. On the other hand, the General Workplace and Lighting checklists did not have any items categorized as behavioral interventions. Environmental interventions were prominently featured in most of the checklists. The Lighting checklist had all items classified as environmental interventions (100% of items). Additionally, the General Workplace (93% of items) and Electrical (92% of items) checklists had a high percentage of items falling under this category. Organizational interventions were found to be more prevalent in certain checklists compared to others. The Policy checklist had the highest proportion of organizational interventions (76% of items).

$$\text{OrderedThreshold} = \langle \text{Threshold.\#Beh} = 4\ , \text{Threshold.\#Org} = 2, \text{Threshold.\#Env} = 0 \rangle$$

#	#Beh	#Env	#Org
Practice1	5	0	2
Practice2	4	5	5
Practice3	4	2	4
Practice4	5	1	3
Practice5	5	0	2
Practice6	4	3	2
Practice7	4	2	2
Practice8	5	1	5
Practice9	5	4	4
Practice10	4	5	3

A

#	#Beh	#Env	#Org
Practice1	**5**	0	2
Practice4	**5**	1	3
Practice5	**5**	0	3
Practice8	**5**	1	5
Practice9	**5**	4	4
Practice2	**4**	5	5
Practice3	**4**	2	4
Practice6	**4**	2	2
Practice7	**4**	3	2
Practice10	**4**	5	3

B

#	#Beh	#Env	#Org
Practice8	**5**	1	**5**
Practice9	**5**	4	**4**
Practice4	**5**	1	**3**
Practice5	**5**	0	**3**
Practice1	**5**	0	**2**
Practice2	**4**	5	**5**
Practice3	**4**	2	**4**
Practice10	**4**	5	**3**
Practice6	**4**	2	**2**
Practice7	**4**	3	**2**

C

#	#Beh	#Env	#Org
Practice8	**5**	**1**	**5**
Practice9	**5**	**4**	**4**
Practice4	**5**	**1**	**3**
Practice5	**5**	**0**	**3**
Practice1	**5**	**0**	**2**
Practice2	**4**	**5**	**5**
Practice3	**4**	**2**	**4**
Practice10	**4**	**5**	**3**
Practice7	**4**	**3**	**2**
Practice6	**4**	**2**	**2**

D

Figure 3: Steps to select prevention practices based on Steps to the example above.

Additionally, the Workstation Design (70% of items) and Chemicals (63% of items) checklists had a high percentage of items falling under this category. The assessment of cost-related interventions indicated a substantial variation across the checklists. The Noise checklist had the highest percentage of expensive items (38%). In contrast, the Electrical, Machine Guarding, and General Workplace checklists did not contain any expensive items. The Electrical checklist had the highest proportion of high-priority items (92%). Other checklists with a notable number of high-priority items included Noise (77% of items), Fire (73% of items), and Chemicals (69%).

Items that fell into multiple intervention categories were observed in certain checklists. Workstation Design had the highest percentage of items classified as both organizational and environmental interventions (50%). On the other hand, 11%, 8%, 7%, 6%, and 3% of the items in the Machine Guarding, Electrical, Temperature, Policy, and Fire checklists, respectively, were not included in any interventions. To provide a clearer understanding of the patterns in expert opinions and strengthen the interpretation of the results, several graphs have been added in Appendix C. These visualizations offer additional insights into the statistical trends observed during the analysis.

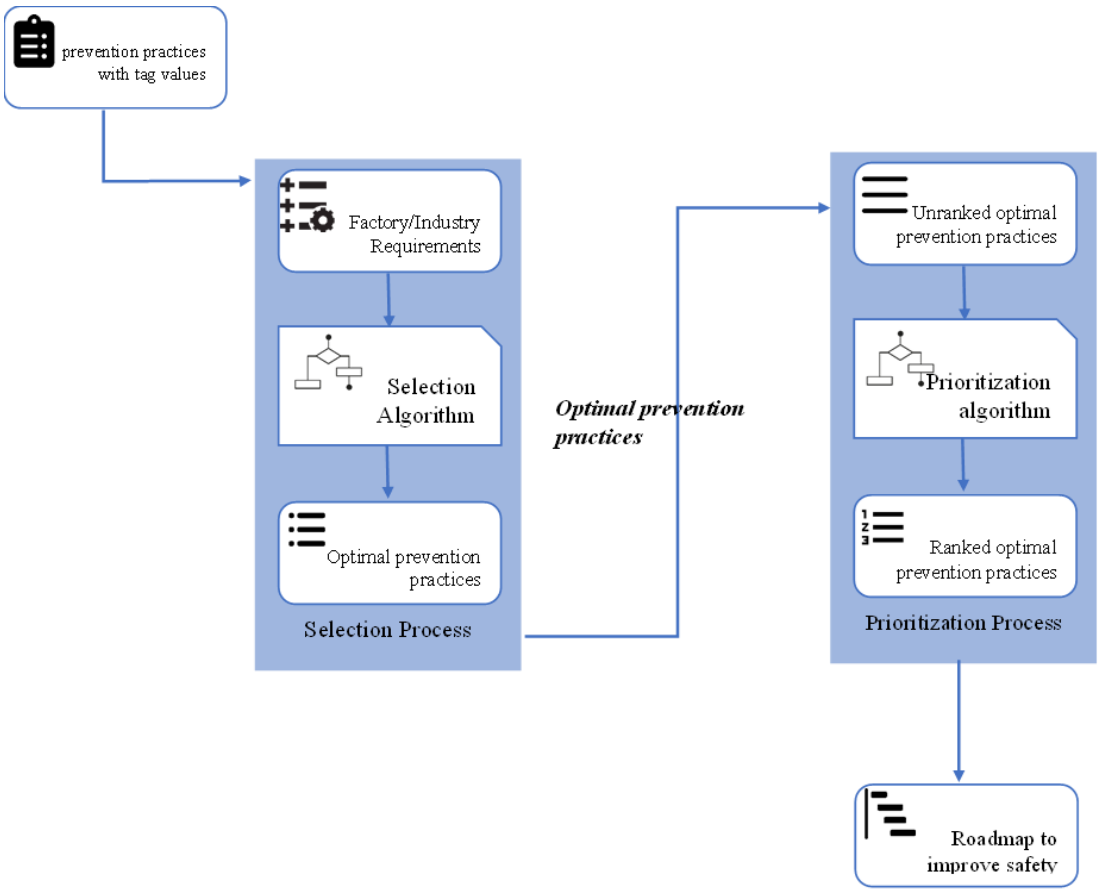

Figure 4: The process of developing a model to prioritize prevention practices based on the needs of an industry

Discussion

The provided statistics in the introduction section highlight the severe impact of occupational accidents, injuries, and diseases, including millions of fatalities, non-fatal injuries, and substantial economic losses equivalent to trillions of dollars worldwide. These significant public health challenges and their associated costs underscore the necessity of identifying influential factors that shape managers' decisions about occupational safety and health programs to enhance occupational health and safety by reducing the occurrence of accidents and improving the well-being of workers.

Preventive programs such as creating a safe work environment and promoting safe worker behavior can play an important role in reducing occupational accidents and their negative consequences.[7] Most of these programs are developed in the form of checklists.[8-11] Because the program tries to cover all aspects of occupational safety and health in the factory/industry, the number of occupational risk prevention practices is usually very high. Implementing all of them requires a lot of financial and human resources and equipment. Therefore, it is necessary to prioritize these practices in the checklists based on the needs of each factory/industry.

In this research, a model including the process of selecting practices and the process of prioritizing practices based on the needs of factories/industries is introduced. For this purpose, four features were determined for each practice based on semi-structured interviews with managers from different factories, which are the cost of doing (Cost tag), the effect that it has on reducing the incidence of occupational accidents or its negative consequences (Priority tag), the type of intervention (Type of Intervention tag) and type of hazard (Type of Hazard tag). The factors mentioned in previous studies have been used separately in the design or evaluate of occupational risk prevention practices. In,[18-20] among the above factors, only the type of hazard is considered. In[8] cost and type of intervention are

considered and in[9,10,13] only type of intervention is considered. The innovation of this study is that all four items have been considered. As a result, in addition to obtaining a comprehensive view of occupational risk prevention practices, we have been able to provide a model for prioritizing these practices.

In this study, the acceptable values for Type of Intervention tag are: Behavioral-Intervention, Environmental-Intervention or Organizational-Intervention. These categories are similar to the categories presented in.[9] In this study, the focus is on all levels, unlike previous studies that concentrated on one or two areas.[13,15,17] The acceptable values for Cost tag are: Low-Cost and Expensive. The acceptable values for Priority tag are: High-Priority and Low-Priority. These values were determined using the Delphi method for each prevention practice in checklist. In the selection process, the input is the type of occupational accidents and the type of interventions determined by the factory decision makers. The output of this process is a subset of the occupational risk prevention practices in the checklists that are match with the inputs. The outputs of this process are given as input to prioritizing process. The output of the prioritization process is a list of practices that have been prioritized based on the proposed Cost-Benefit model. The model divides practices into four categories based on Cost tag and Priority tag. According to the proposed Cost-Benefit model, Low-Cost High-Priority practices have the highest priority for implementation. Low-Cost Low-Priority practices and Expensive High-Priority practices are the next priorities. Low-Priority Low-Cost practices have the lowest priority. The Cost-Benefit model is based on the Eisenhower's Urgent/Important Principle, which has been used in many studies.[42-44]

Unlike previous studies that focused on a limited industry,[8,9,11-13] this study presents a model with numerous potential applications across various industries. Firstly, it can be harnessed to develop comprehensive and tailored occupational safety programs to suit the unique needs and characteristics of each factory or industry. By assisting in the selection and prioritization of preventive practices, the model ensures that the chosen measures are highly relevant and impactful in reducing occupational accidents and enhancing worker safety. Secondly, the model becomes an invaluable tool for decision-makers in efficiently allocating limited financial, human, and equipment resources. By considering cost and priority tags, preventive practices are ranked in order of importance, directing resources towards implementing measures that offer the greatest benefit in terms of accident reduction and mitigating negative consequences.

Additionally, the model supports risk assessment[12,16] and management processes by thoughtfully considering the type of hazards and interventions. This enables targeted implementation of preventive measures, effectively addressing specific risks and enhancing overall safety outcomes. Decision-makers are empowered to make informed choices about prioritizing practices based on their potential to reduce risks and improve safety. Moreover, the model facilitates continuous improvement efforts in occupational safety and health. By allowing for regular review and updating of the prioritized list of practices as new information becomes available, the safety program remains dynamic and responsive to changing needs and emerging risks within the industry.

Lastly, industries can leverage the model to align their occupational safety practices with compliance standards and regulatory requirements.[16] By incorporating practices that effectively address specific hazards and interventions, factories can demonstrate their commitment to ensuring a safe work environment and fulfilling legal obligations.[16]

The proposed model offers several significant advantages. Firstly, it is designed to be checklist-independent, allowing its application regardless of the specific occupational safety and health checklist being used. This inherent flexibility enables easy substitution of different checklists by simply determining the defined tags for each relevant occupational risk prevention practice. As a result, the model can be seamlessly integrated into various occupational safety and health frameworks, streamlining the decision-making process.

Moreover, the model is highly adaptable and caters to managers' diverse priorities, making it relevant and applicable across a wide range of settings, from small workshops to large factories. By tailoring the model to their specific needs and preferences, managers can obtain a comprehensive list of prioritized prevention practices tailored to their unique operational context. This level of customization ensures that the model effectively supports decision-making processes in occupational safety and health, empowering managers with well-informed and relevant insights.

In summary, the proposed model's checklist-independent and flexible nature, combined with its ability to accommodate managers' priorities, positions it as a valuable and practical tool in enhancing workplace safety and health. By promoting informed decision-making and offering adaptable solutions, the model serves as a strategic asset for effectively managing occupational risks and fostering a safer and healthier work environment across diverse industries.

This study encountered three four limitations. Firstly, while great care was taken to ensure the expertise and experience of the selected panel, it is important to acknowledge some inherent limitations that may arise from the expert selection process. One potential bias stems from the fact that all selected experts were drawn from the Mashhad Fire and Safety Services Organization. Although these individuals possess a minimum of 10 years of experience and have been involved in evaluating safety practices across a range of industries, their perspectives may still reflect the operational context of their organization, which could introduce a degree of organizational bias. Their familiarity with specific practices and protocols within their operational framework might influence their judgment.

The second limitation lies in conducting the Delphi method with the experts were all drawn from a single organization and city, specifically the Mashhad Fire and Safety Services Organization. This could introduce a degree of bias, as the perspectives and experiences of these experts may not fully represent those in other industries or regions. The generalizability of the findings is thus limited. Expanding the Delphi panel to include experts from a wider range of cities, regions, and organizations involved in occupational safety and health would have provided a more diverse set of viewpoints, potentially leading to more robust and generalized conclusions. Additionally, while the selected experts were highly knowledgeable in their respective areas, the scope of their expertise may not fully cover all key aspects of occupational safety across different industries, which could further limit the broader applicability of the results. Finally, in the semi-structured interviews conducted solely with the managers of the organizations, incorporating the perspectives of workers at various levels can enhance the model.

To overcome these limitations and enhance the model's robustness, future research endeavors should aim to address the aforementioned shortcomings. By incorporating a more diverse group of experts and worker from various organizations and geographic locations, the study can attain broader applicability and validity in its conclusions.

Furthermore, to provide quantitative structures for determining the valid range of factors, researchers can consider implementing additional data-driven analyses. Utilizing statistical methods to complement the qualitative assessments can strengthen the model's foundation and refine the prioritization process.

Authors Contributions: M. Mahdi Barati Jozan: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, draft preparation. Aynaz Lotfata: Methodology, Validation, Formal analysis, Review, Supervision. Saifuddin Khalid: Methodology, Validation, Formal analysis, Review. Hamed Tabesh: Conceptualization, Methodology, Validation, Formal analysis, Review, Supervision.

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Appendix A: Questions of the semi-structured questionnaire

The semi-structured interview questionnaire designed to extract critical influencing elements affecting the implementation of prevention practices in factories/industries:

Introduction:

- Can you please introduce yourself and your role within the factory/industry?
- How long have you been working in this position, and what are your main responsibilities regarding occupational safety and accident prevention?

General Understanding:

- How would you describe the current approach to occupational safety and accident prevention practices in your factory?
- What are some of the key challenges or barriers you encounter when implementing prevention practices?

Identification of Influential Factors:

- From your perspective, what do you believe are the most critical factors influencing the prioritization of prevention practices in our factory/industry?
- Can you elaborate on any specific incidents or experiences that have highlighted the importance of certain prevention practices over others?
- Are there any external factors, such as regulatory requirements or industry standards, that significantly influence your decision-making regarding prevention practices?

Conclusion:

- Is there any additional information or insights you would like to share regarding the prioritization and implementation of prevention practices in our factory?
- Do you have any final thoughts or recommendations for improving our approach to occupational safety?

Appendix B: The results of the Delphi method

Due to the high number of prevention practices (146 practices) in the checklists, only the first 3 prevention practices of the ILO Checklist for Chemicals are shown in the tables below (**Table A1**, **Table A2**, **Table A3**). "Do any processes in the factory produce dusts, fumes, mists or vapours?", "Are exhaust ventilation systems in use to reduce the levels of dusts, fumes, mists or vapours in the sections?", and "Is a physical inventory done of chemicals stored/used in the work area?" are the first three prevention practices of the ILO Checklist for Chemicals. A complete list of prevention practices is available on a local site for users.

Table A1: Delphi method output for the $\text{Practice}_{\text{Chemicals},1}$.$practice_{Chemical,1}$ is the first prevention practice on the Chemicals checklist

Expert	Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Expert_1$	$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	○High-Priority ●Low-Priority	○Low-Cost ● Expensive
$Expert_2$	$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	☐Behavioral-Intervention ☑Environmental-Intervention ☑Organizational-Intervention	○High-Priority ●Low-Priority	○Low-Cost ●Expensive
$Expert_3$	$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	●Low-Cost ○Expensive
$Expert_4$	$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	☑Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	●Low-Cost ○Expensive
$Expert_5$	$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	☑Behavioral-Intervention ☐Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	○Low-Cost ●Expensive

Table A2. Delphi method output for the $\text{Practice}_{\text{Chemicals},2}$. $practice_{Chemical,2}$ is the second prevention practice on the Chemicals checklist

Expert	Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Expert_1$	$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	○Low-Cost ● Expensive
$Expert_2$	$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	☐Behavioral-Intervention ☑Environmental-Intervention ☑Organizational-Intervention	○High-Priority ●Low-Priority	●Low-Cost ○Expensive
$Expert_3$	$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	○Low-Cost ●Expensive
$Expert_4$	$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	○High-Priority ●Low-Priority	●Low-Cost ○Expensive
$Expert_5$	$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	○Low-Cost ●Expensive

Table A3. Delphi method output for the $\text{Practice}_{\text{Chemicals},3}$. $practice_{Chemical,3}$ is the third prevention practice on the Chemicals checklist

Expert	Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Expert_1$	$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	☐Behavioral-Intervention ☑Environmental-Intervention ☐Organizational-Intervention	●High-Priority ○Low-Priority	● Low-Cost ○Expensive
$Expert_2$	$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	☐Behavioral-Intervention ☑Environmental-Intervention ☑Organizational-Intervention	○High-Priority ●Low-Priority	○Low-Cost ● Expensive
$Expert_3$	$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	☐Behavioral-Intervention ☑Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive
$Expert_4$	$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	☐Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	○ High-Priority ●Low-Priority	○ Low-Cost ● Expensive
$Expert_5$	$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	☐Behavioral-Intervention ☐Environmental-Intervention ☑Organizational-Intervention	●High-Priority ○Low-Priority	○ Low-Cost ● Expensive

The summary of experts' votes on the $\text{Practice}_{\text{Chemicals},1}$, $\text{Practice}_{\text{Chemicals},2}$ and $\text{Practice}_{\text{Chemicals},3}$is shown in **Table A4.**

Table A4. The summary of experts' votes on the $\text{Practice}_{\text{Chemicals},1}$, $\text{Practice}_{\text{Chemicals},2}$ and $\text{Practice}_{\text{Chemicals},3}$

Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	Behavioral-Intervention (2) Environmental-Intervention (3) Organizational-Intervention(2)	High-Priority (3) Low-Priority (2)	Low-Cost (2) Expensive (3)
$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	Behavioral-Intervention (0) Environmental-Intervention (5) Organizational-Intervention(1)	High-Priority (3) Low-Priority (2)	Low-Cost (2) Expensive (3)
$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	Behavioral-Intervention (0) Environmental-Intervention (3) Organizational-Intervention(4)	High-Priority (4) Low-Priority (1)	Low-Cost (0) Expensive (5)

According to the **Table A5,** the selected tags for each prevention practice are shown in **Table A6.** For each prevention practice, only tags with 3 or more votes are assigned.

Table A6. Selected tags for the $\mathbf{Practice}_{\mathbf{Chemicals,1}}$, $\mathbf{Practice}_{\mathbf{Chemicals,2}}$ and $\mathbf{Practice}_{\mathbf{Chemicals,3}}$. The numbers in parentheses are the number of votes.

Checklist	PracticeName	#TypeOfIntervention	#Priority	#Cost
$Checklist_{Chemicals}$	$Practice_{Chemicals,1}$	Environmental-Intervention (3)	High-Priority (3)	Expensive (3)
$Checklist_{Chemicals}$	$Practice_{Chemicals,2}$	Environmental-Intervention (5)	High-Priority (3)	Expensive (3)
$Checklist_{Chemicals}$	$Practice_{Chemicals,3}$	Environmental-Intervention (3) Organizational-Intervention(4)	High-Priority (4)	Expensive (5)

The number in parentheses shows the number of votes cast for the prevention practice. This number is used as the weight of the tag. For example, $Practice_{Chemicals,2}$ is an environmental intervention or $Checklist_{Chemicals,3}$ is an expensive prevention practice. But there is less certainty that $Checklist_{Chemicals,1}$ is a high priority prevention practice. $Checklist_{Chemicals,3}$ is an environmental and organizational intervention. Tags with three votes have the least consensus. For example, high priority and expensive tags for $Practice_{Chemicals,1}$ have the least consensus. Tags with 5 votes have the most certainty, tags with 3 votes have the least certainty, and tags with 4 votes are named as medium certainty. The prevention practices with high, medium and low certainty are marked with green, blue and orange colors, respectively.

Appendix C: The results of the Delphi method

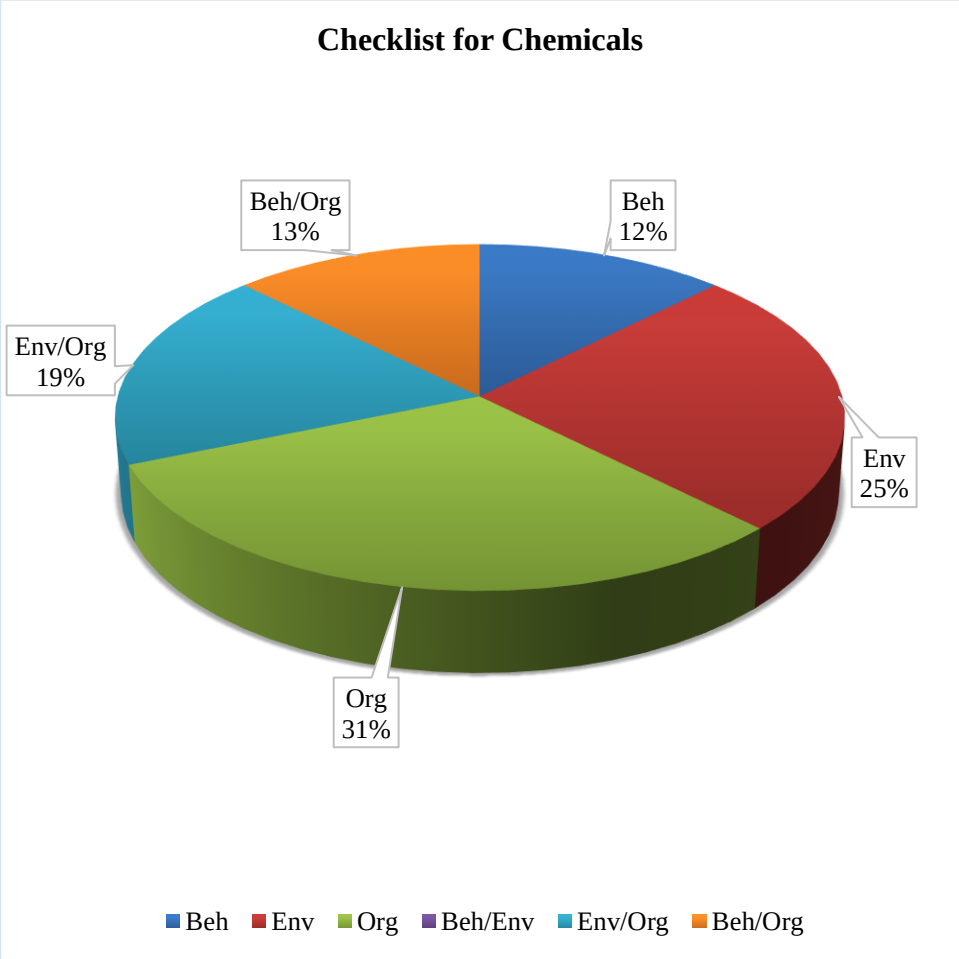

Figure A1: The prevalence of types of interventions in prevention practices across the checklist for Chemicals (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

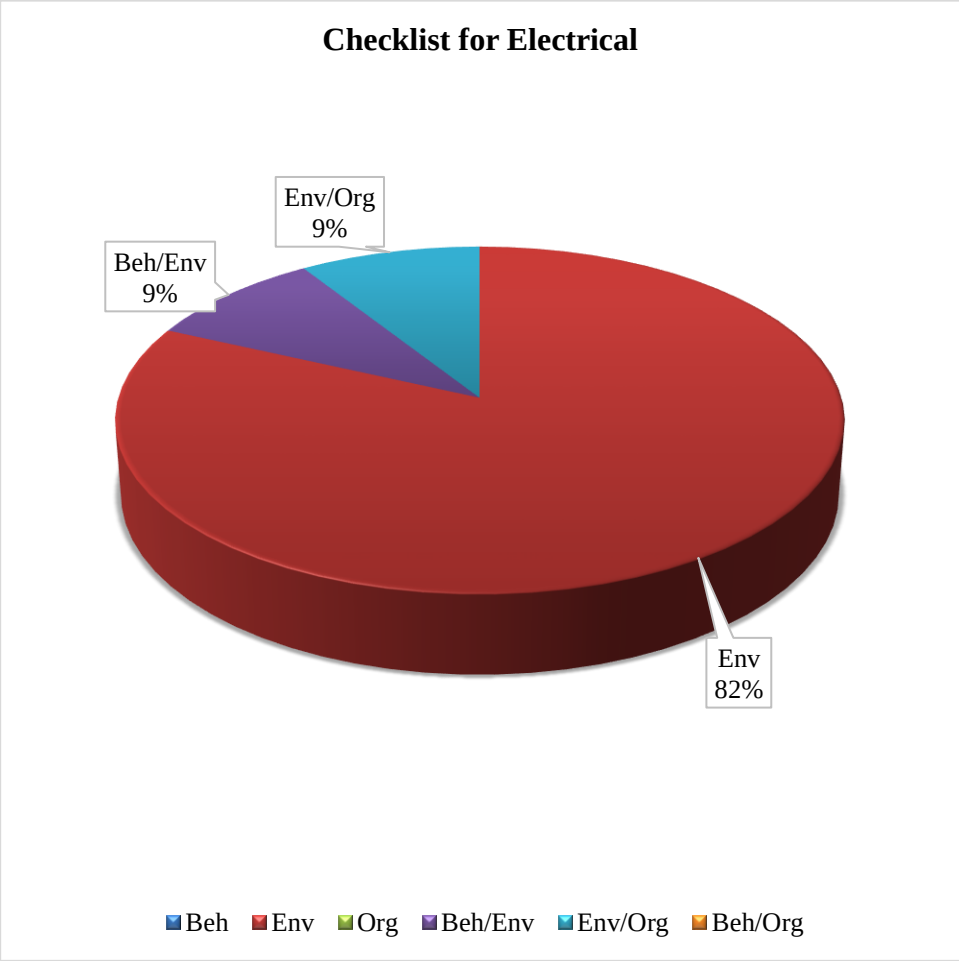

Figure A2: The prevalence of types of interventions in prevention practices across the checklist for Electrical (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

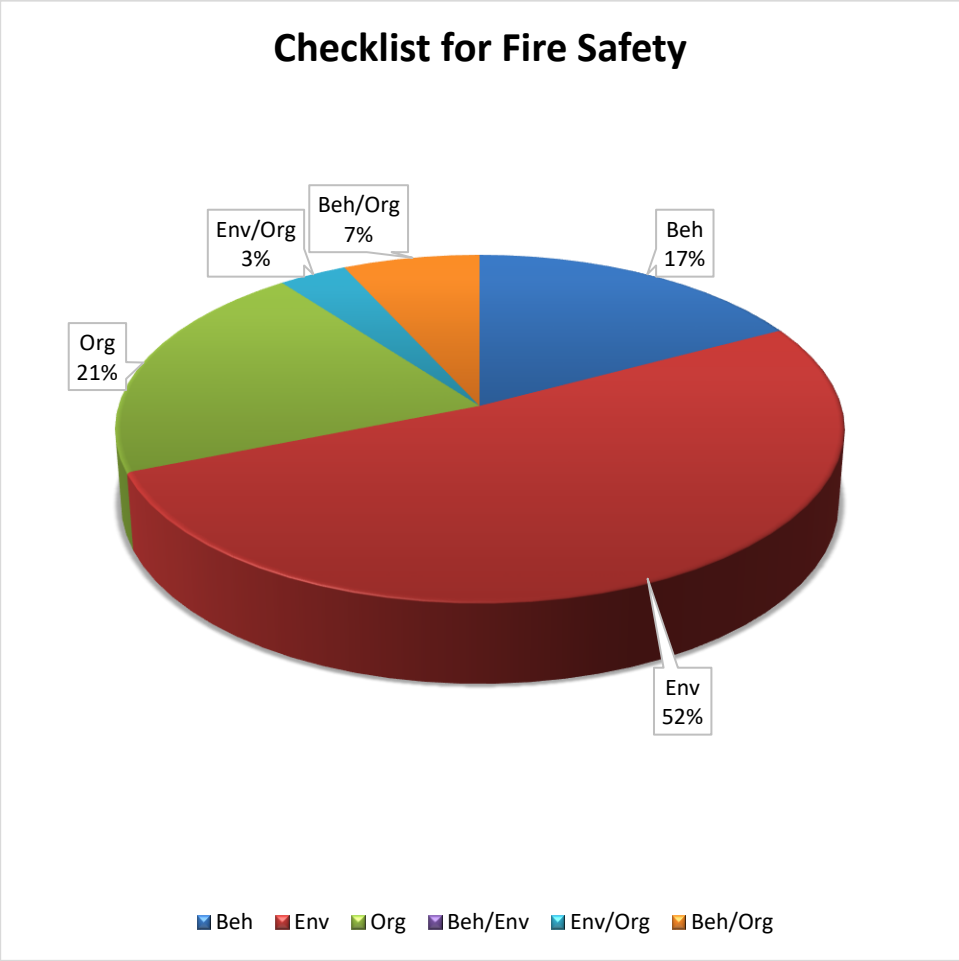

Figure A3: The prevalence of types of interventions in prevention practices across the checklist for Fire Safety (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

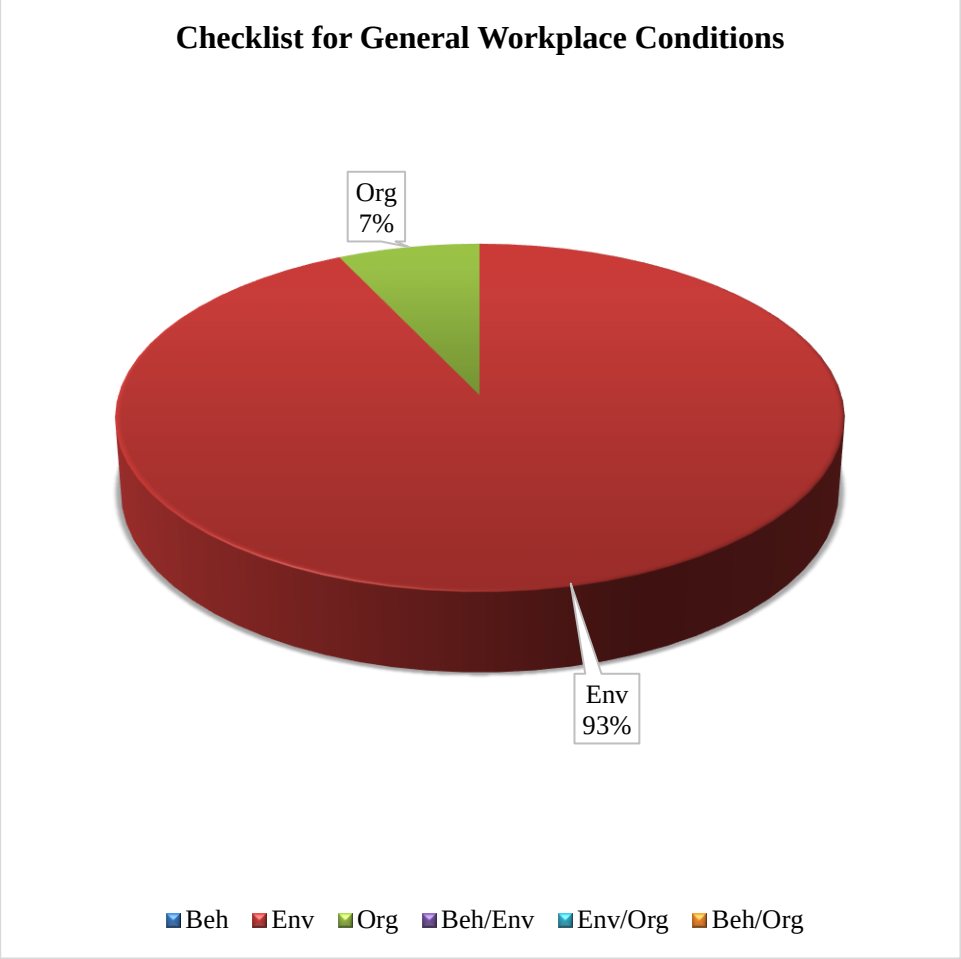

Figure A4: The prevalence of types of interventions in prevention practices across the checklist for General Workplace Condition (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

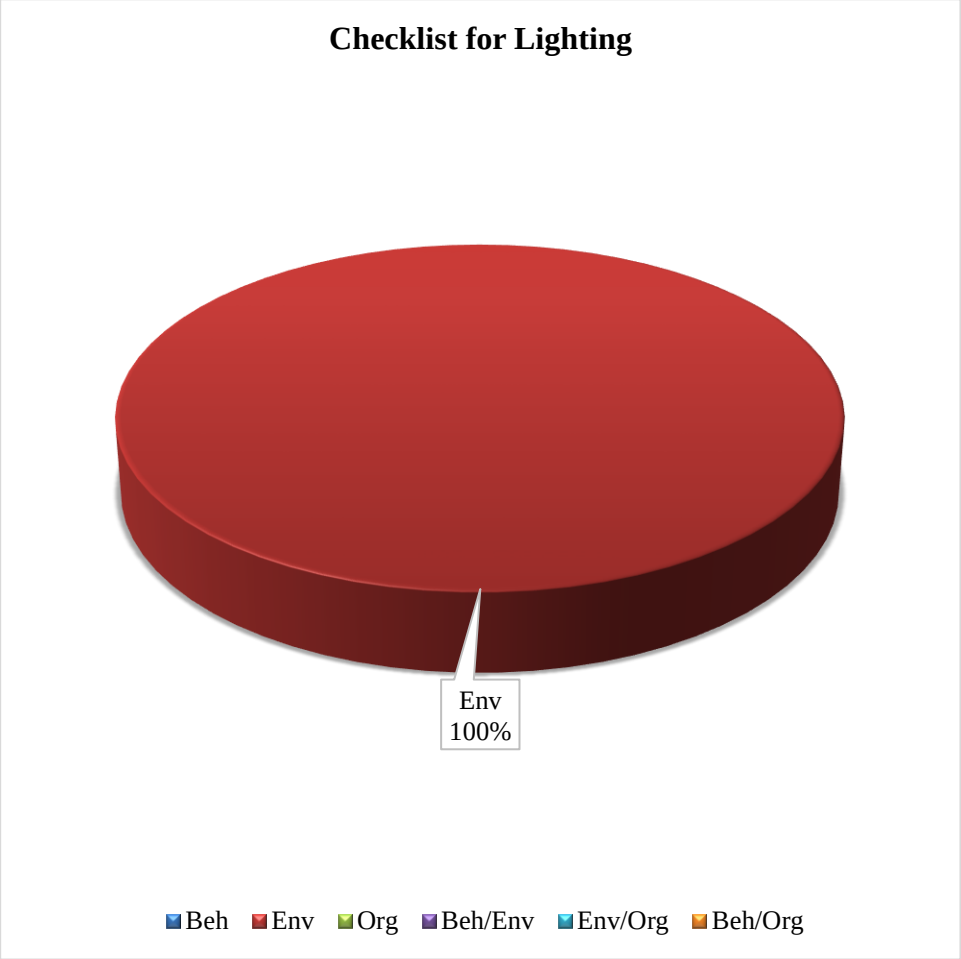

Figure A5: The prevalence of types of interventions in prevention practices across the checklist for Lighting (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

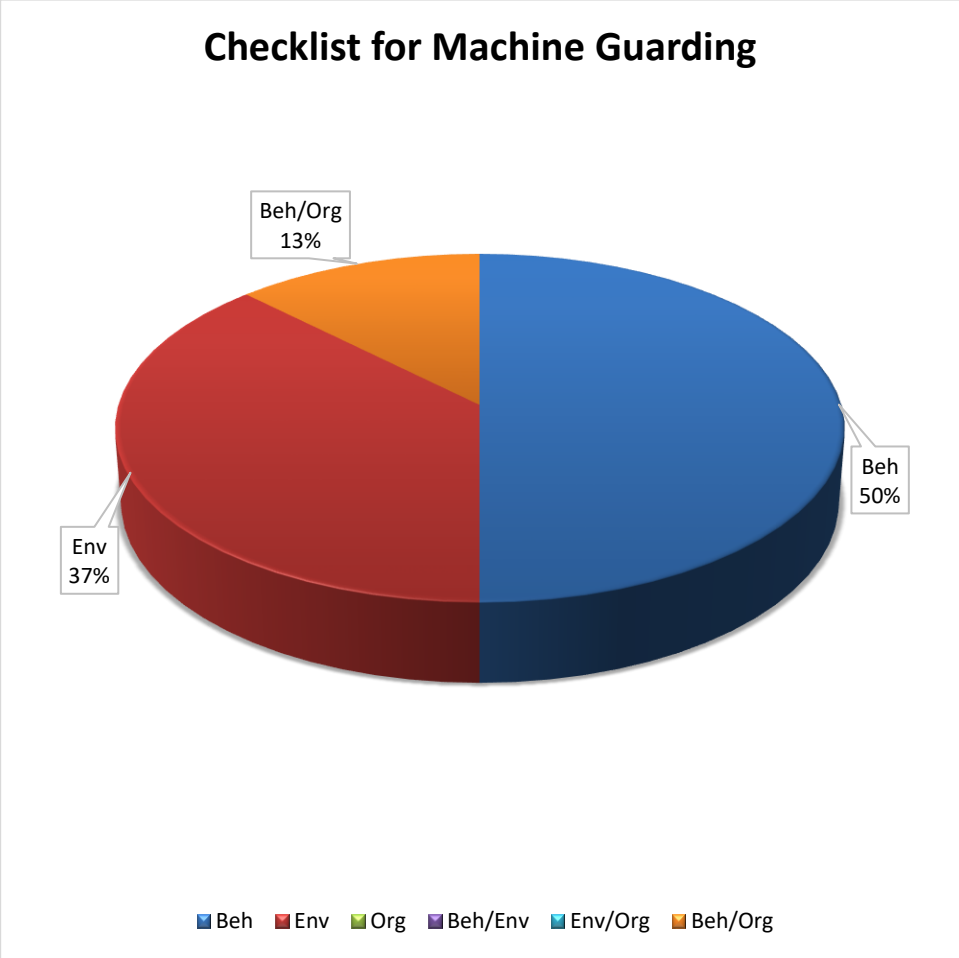

Figure A6: The prevalence of types of interventions in prevention practices across the checklist for Machine GUarding (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

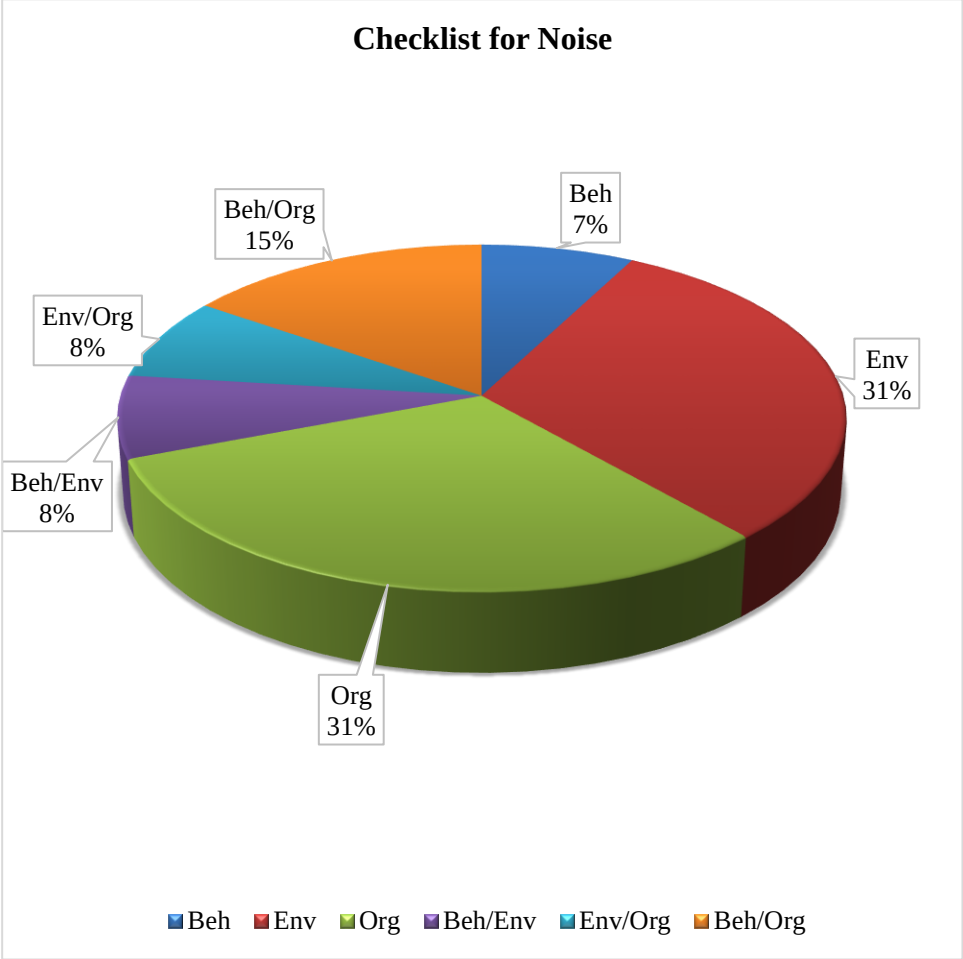

Figure A7: The prevalence of types of interventions in prevention practices across the checklist for Noise (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

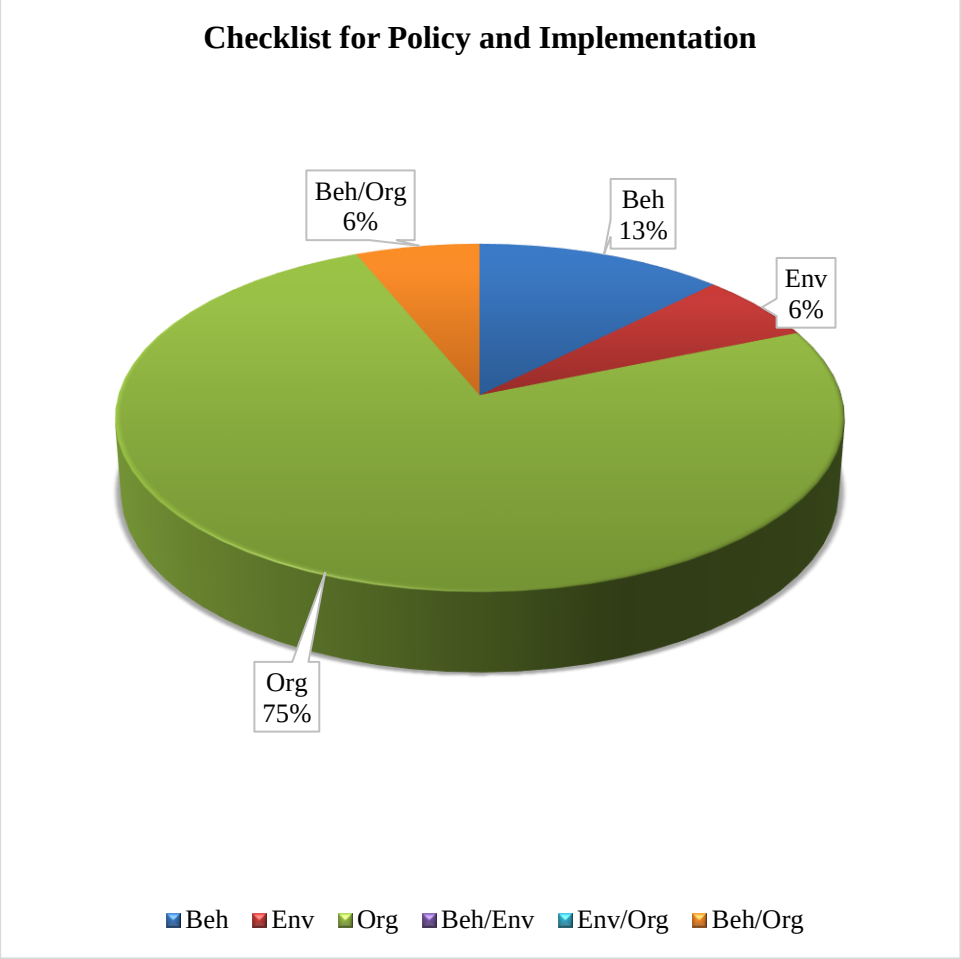

Figure A8: The prevalence of types of interventions in prevention practices across the checklist for Policy and Implementation (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

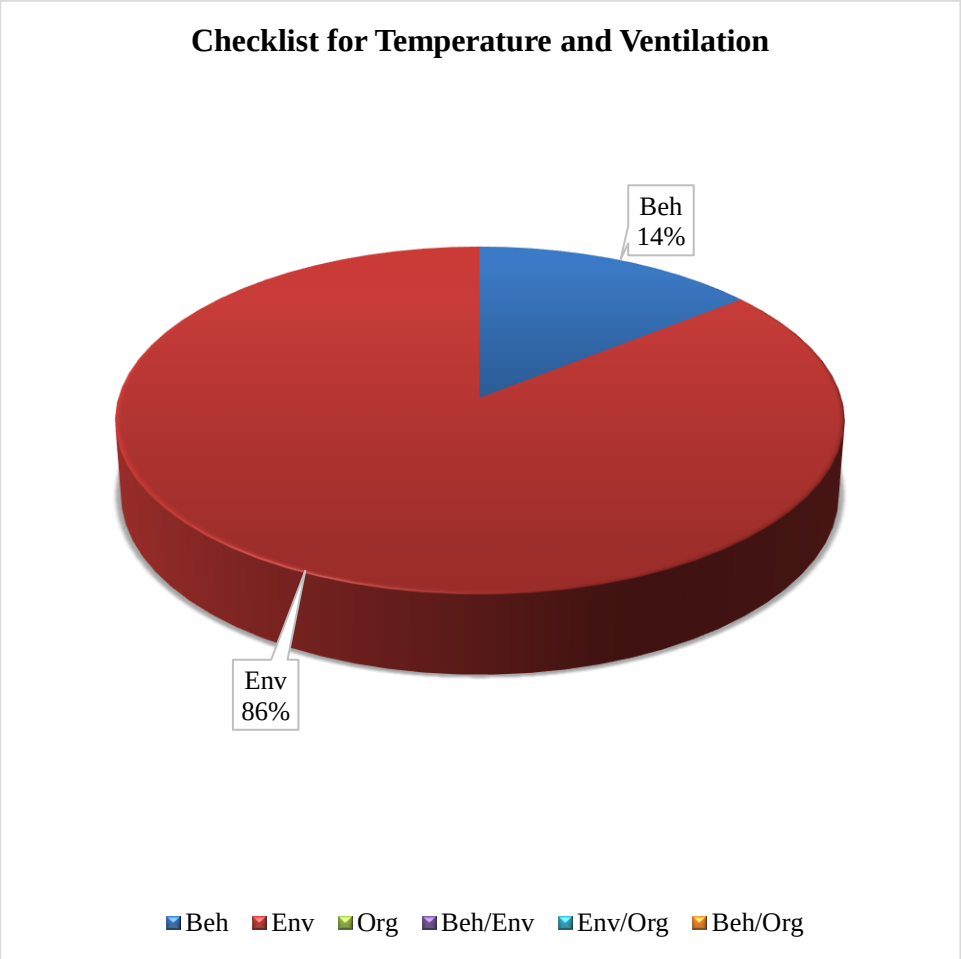

Figure A9: The prevalence of types of interventions in prevention practices across the checklist for Temperature and Ventilation (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

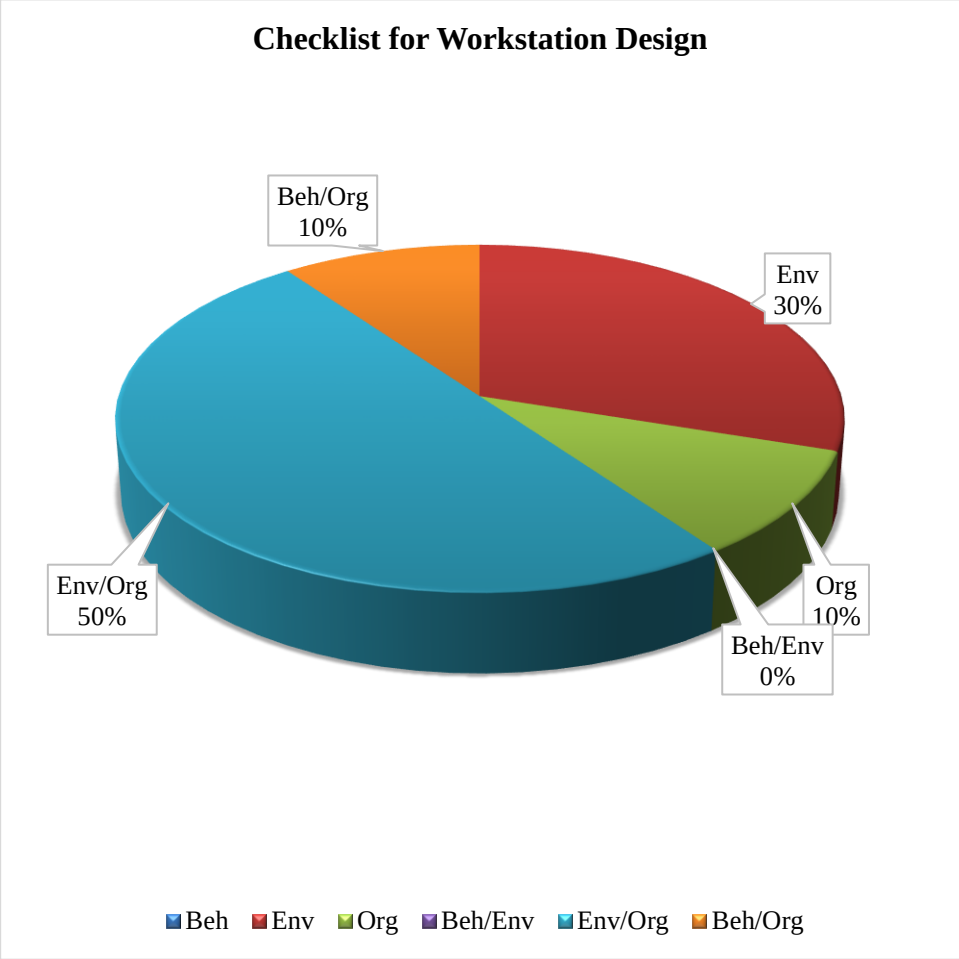

Figure A10: The prevalence of types of interventions in prevention practices across the checklist for Workstation Design (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

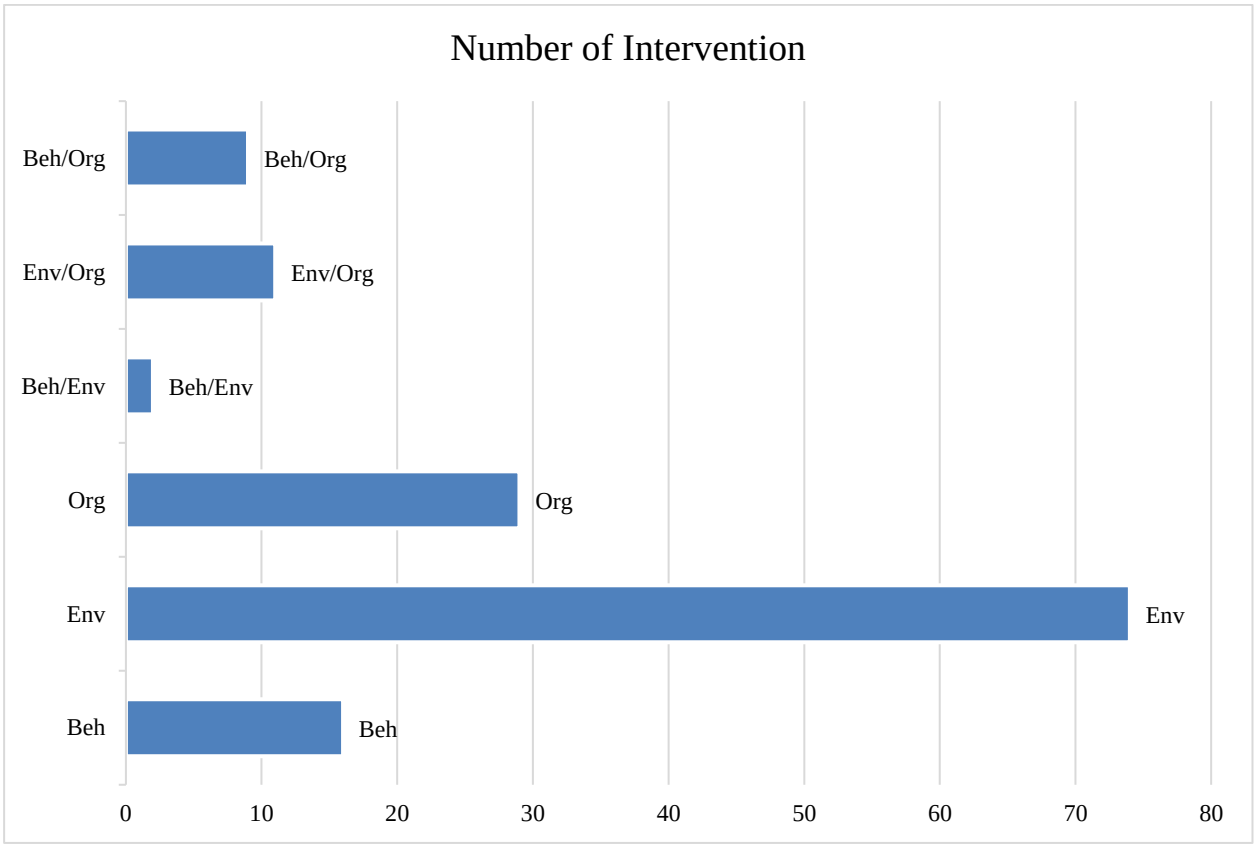

Figure A11: The prevalence of types of interventions in prevention practices across all checklists (Beh: Behavioral intervention; Env: Environmental intervention; Org: Organizational intervention; Beh/Env: Behavioral and Environmental intervention; Env/Org: Environmental and Organizational intervention; Beh/Org: Behavioral and Organizational intervention)

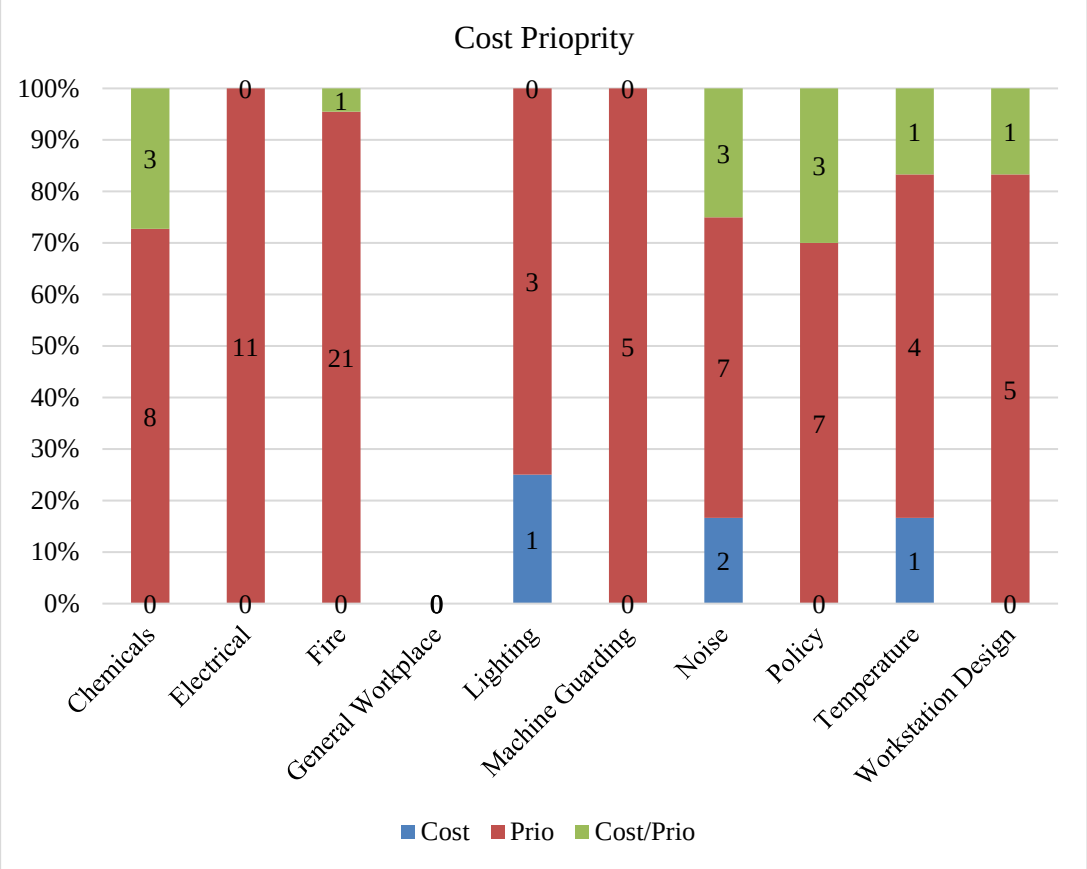

Figure A12: The number of types of Expensive and High-Priority interventions in prevention practices across each checklist (Cost: Expensive intervention; Prio: High-Priority intervention; Cost/Prio: High-Priority and Expensive intervention)