Ergonomics Management in the Workplace (Introducing to TUGA Ergonomics Management & Analysis Model: TEMA)

By:

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Foreword

Nowadays, paying attention to ergonomic principles by focusing on all its dimensions in workplaces in order to improve people's health and productivity and excellence of organizations is very important. Physical ergonomics is one of the important dimensions of ergonomics on which many studies and evaluations have been conducted. Previous studies have shown that one-dimensional assessments in the field of ergonomics (physical ergonomics) are not effective and effective studies in this field require comprehensive attention to all aspects of ergonomics (physical, environmental, cognitive and organization) with a comprehensive approach focusing on continuous improvement cycles and resilience engineering.

Therefore, considering the importance of this issue, increasing the prevalence of ergonomic disorders in different industries and organizations, lack of similar evaluation models, the essential role of ergonomics in improving the health of employees and increasing productivity, "comprehensive model of ergonomics management in the workplace" was developed and implemented for the first time in the Iran in a power plant equipment industry.

The authors' efforts in this book have been based on providing the most important and practical principles in the field of occupational ergonomics and also have a special look at the field of ergonomic management in the workplace. It should be noted that the measurement tools expressed in this book are suggested in order to study the score levels of ergonomic risk factors and experts can choose their tools and methods according to their needs and using the proposed ergonomic management model (including 8-steps).

One of the advantages of this book is the description of an ergonomic management model in the workplace. It is hoped that this book is an effective step towards proper establishment of management cycle and evaluation of ergonomics in order to reduce ergonomic risk factors in the workplace.

The present model has been developed with the participation of 30 Industry experts and university professors. Therefore, the authors express their gratitude and appreciation for their contribution.

It is obvious that despite the efforts made to write the present book better, its first publication is not free of problems, however, we sincerely press the hands of all professors, students, experts and audiences who add to the value of this work by sending their valuable comments to the following e-mail address:

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Finally, the authors would like to express their special thanks to the TUGA Company, MAPNA group, and the experts involved in the study.

Best Regards.

Be Safe and Sound ...

September 2023.

Chapter 1.

Introduction

Introduction

Ergonomics is the modification and optimization of the environment, tools, equipment and machine from two physical and cognitive dimensions in order to enhance the level of health and physical, mental and social well-being through the interaction of people with each other and other components of the system or environment.

In the other words, Ergonomics is the process of designing or arranging workplaces, products and systems so that they fit the people who use them.

Most people have heard of ergonomics and think it is something to do with seating or with the design of car controls and instruments – and it is… but it is so much more. Ergonomics applies to the design of anything that involves people – workspaces, sports and leisure, health and safety.

Ergonomics (or 'human factors' as it is referred to in North America) is a branch of science that aims to learn about human abilities and limitations, and then apply this learning to improve people's interaction with products, systems and environments.

International Ergonomics Association definition: "Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

Ergonomics is a science-based discipline. It brings together knowledge from anatomy and physiology, psychology, engineering and statistics and ensures that the designs complement the strengths and abilities of people who use it.

Ergonomics aims to improve workspaces and environments to minimize risk of injury or harm. So as technologies change, so too does the need to ensure that the tools we access for work, rest and play are designed for our body's requirements.

In general, any disproportionate job needs and physical and mental ability of the worker with the duties of the worker can lead to inappropriate and non-ergonomic conditions and can causes human error, accident, injury and ultimately reduces productivity and effectiveness.

The general goals of ergonomics in the workplace include the following:

1. Increased performance
2. Improving the level of physical and mental health

3. Greater efficiency
4. Better quality of products
5. Reducing work pressure and fatigue with proper design of workstations
6. Error and accident prevention

Why is Ergonomics important?

- In workplace, when body is stressed by an awkward posture, extreme temperature, or repeated movement, the musculoskeletal system can be affected. Hence ergonomics play major role in reducing these work related injuries or illness like computer vision syndrome, neck and back pain, and carpal tunnel syndrome etc.
- To create safe, comfortable and productive workspaces by bringing human abilities and limitations into the design of a workspace, which includes the individual's body size, strength, skill, speed, sensory abilities and attitudes.
- To make employees more comfortable and increase productivity.

How does Ergonomics work?

Data and information are collected from various disciplines and is used to design an equipment, modify or rearrange them in a way that it benefits people using them and helps to reduce the risk injuries that can happen.

- **Anthropometry:** body sizes, shapes; populations and variations
- **Biomechanics:** muscles, levers, forces, strength
- **Environmental physics:** noise, light, heat, cold, radiation, vibration body systems: hearing, vision, sensations
- **Applied psychology:** skill, learning, errors, differences
- **Social psychology:** groups, communication, learning, behaviors.
- **Mechanical and industrial engineering**
- **Industrial design**
- **Information design**
- **Kinesiology**
- **Physiology**

In general, four main areas of ergonomics including physical (hardware and work design), environmental, cognitive and organizational (macro ergonomics) have been proposed by the International Ergonomics Association. Physical ergonomics is mainly related to concepts such as anatomy, anthropometry, work physiology, inappropriate posture, workstation analysis and occupational biomechanics. Environmental ergonomics mainly includes the effect of physical harmful factors of the workplace such as noise and vibration, lighting and heat stress on human performance and the application of this information in the design and redesign of human activity environment. Cognitive or perceptual ergonomics are related to thought processes such as perception, memory, stress, mental workload and body reaction to these stressors. Finally, organizational ergonomics is related to optimization of technical-organizational systems such as structures, policies and processes, which in some ways can involve all people of the organization at all levels according to their job duties with ergonomics issues and lead the organization towards studying ergonomic goals and promoting organizational productivity.

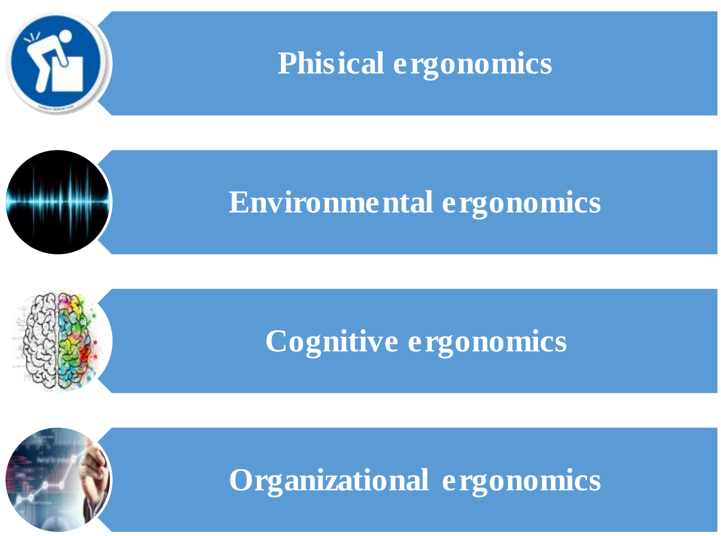


Figure 1 - Classification of different components of ergonomic science

In recent years, due to the increasing extent of industries and human confrontation with machine and various simple equipment and tools and complex systems and the necessity of paying attention to the major problems in the industry, the need for ergonomics has been created and so far has played an effective role in promoting the health of people in different jobs.

In developing countries such as Iran, although some measures have been taken in this regard, we are still at the beginning of the road and perhaps one of the most important reasons is the lack of a macro and organizational view of ergonomics, lack of coordination of the industry sector and comprehensive training and planning, and the lack of efficient and specialized human resources in the field of ergonomics. One of the most important complications caused by non-compliance with ergonomic principles in the workplace is the increase in the frequency rate of prevalence, severity and disabilities caused by the mentioned disorders in people's daily life.

Is ergonomics worth spending?

The correct ergonomics is worth every second and every money you spend. There is a lot of scientific evidence to confirm the economic cost of creating and developing good ergonomics. The increase in employee productivity in the last century has been largely due to increased level of education as well as ergonomics improvements. Companies owe good ergonomics to increasing the market share of their new products, which is the product of creating a pleasant customer experience. Reducing the reliance on people's skills to do things is the result of easier tasks and one of the good ergonomic products.

The wrong ergonomics destroys not only productivity but also your mood and passion for working. Despite such a profound psychological effect, Feather is clear that the possible costs seem reasonable. However, today there are many cost-benefit methods that can be used before any control and corrective measures are taken. A sample of empirical equations created in the present model is demonstrated to estimate the parameters related to ergonomics economy in the following description of the model.

To achieve good ergonomics, you need to know what you want; which color, shape, design, size, etc. is best suited for you. It's best to try out a pilot scheme before final implementation, especially if you're going to pay a high price for it. It is your natural right to expect things to be easier and must be realized. Don't forget that there is no magical ergonomics that work for everyone and everywhere! If someone defines their extraordinary ergonomics, that doesn't mean that ergonomics is right for you, too. Ergonomics is a personal concept, you need to know your physical characteristics, the nature of your work and your habits, and see if everything matches you and the circumstances around you.

Sometimes in some cases education is necessary. It doesn't necessarily mean bad ergonomics just reflects the inevitable complexity of some things. In these cases, you should consider:

1. How much training is required?
2. How much money is required for training?
3. If training is interrupted, how difficult will it be to resume?
4. Are the benefit(s) worth the cost and effort?

But you need to know that you need to act as soon as possible to achieve the best results. 95% of your logistical resources should be spent on the first 10% of the project's life cycle. In other words, if you act efficiently from the start, you get the most out of the product or service cycle.

Increasing productivity by following the rules of ergonomics

If ergonomics has been performed in the workplace, it takes into account all the tasks that employees routinely have to perform.

If a staff member needs a variety of files throughout the day, and each time they use the files, they have to leave their desk and travel a distance to the file storage, it is clear that in the design of this person's desk, no one has paid attention to the ergonomics rules. The time wasted each time you leave the desktop, the likelihood of causing damage with each access to one of the files or even the fall of heavy objects on the person, are all of the factors that have been overlooked in this environment.

Ergonomics in the workplace can increase employee productivity and their work benefits. If people's workplaces are uncomfortable or boring, they can't work at their maximum speed and efficiency. In addition, if one of the people is injured in the workplace, by interrupting one part, the overall productivity of the organization decreases.

Increasing the morale and strength of employees by following the rules of ergonomics

Other reasons for the importance of ergonomics in the workplace are improving the morale and productivity of employees. Ergonomics in the workplace, mentally, causes satisfaction of the people present in that environment and the satisfaction and morale of the people will increase clearly. Employees who feel they have value and dignity for the employer prefer to work longer in that complex and reduce the likelihood of work leaving. Making even the smallest changes can have a tremendous impact on the organization's costs.

When the employer takes into account the personal needs of the employees and implements ergonomics in the workplace, people will have more appreciation for the employer. There are various examples for considering personal needs, such as ordering an ergonomic chair for a employees that is taller, taking into account the weight of one person and providing them with a suitable seat, or providing a ergonomic mouse for someone who feels pain in the wrist area.

These things to observe ergonomics not only cause personal satisfaction, but also increase productivity in the workplace and speed of work.

Cost of injuries in the workplace

Workplace injuries are very costly when ergonomics is not implemented well in the workplace, even regardless of the amount of psychological damage that a workplace injury causes to the individual, family and friends. According to research conducted in this area, the injuries and caused by the workplace in 2013 were about $61 billion, including direct costs and indirect costs, i.e. reducing the organization's annual profits.

The most common injuries in the workplace are joint, ligament and muscle injuries. Another common workplace injury is tendon injury, which is about 44 percent of serious injuries. If the work environment is designed based on ergonomics, it can prevent most of these injuries.

When an employee is hurt and forced to quit their job, the organization needs to find a suitable alternative to that employee. The complex must train the work to the new person and wait for weeks for the new employee to dominate their work in order to achieve the former's productivity.

Besides that, the injured employee requests compensation, which will increase the same costs. If the injury is serious, it may lead to a person's redistribution and the cost of training him or her in another post, which will increase the cost of training. So not implementing ergonomics in the workplace will cost the organization more.

The ultimate goal of ergonomics

The ultimate goal of ergonomics is to improve the workspace and environment to reduce risk and harm, as new technologies arise or change, the need to ensure that tools coordinate with the human body. With lifestyle changes, most things are done in sitting position, followed by increased musculoskeletal pains and diseases, so that back pain and musculoskeletal diseases are known as the main cause of disability in the world. Sitting incorrectly and prolonged puts a lot of pressure on the musculoskeletal structure of the body, ergonomic equipment is needed to sit properly. Ergonomic office products such as stand monitors (Monitor support base, sub-monitor), medical dorsal, and etc. can reduce pressures on joints and muscles and reduce musculoskeletal pains and diseases.

Medical studies and growing statistics on headaches, back pain, neck pain, coccyx pain, lumbar disc and other spinal diseases have proven the risks of prolonged and incorrect sitting. Reduced productivity, disability, increased hours of absenteeism, early fatigue, depression and job dissatisfaction, etc. are problems that are caused by pain and illness for employees.

Reducing stress, improving the immune system, mood, breathing and oxygen supply to the brain and increasing confidence are the effects of putting the body in the right position. In addition to all these positive individual impacts, paying attention to improving the economic situation, increasing productivity, reducing health costs, improving health of employees, as well as respect for human dignity have made the use of ergonomic products an indicator of sustainable development.

Work-related musculoskeletal disorders (WRMSDS)

Work-related musculoskeletal disorders (WRMSDS) are among the most common types of occupational diseases and injuries, and the main cause of workers' disability and injury, loss of working time, increased costs and economic losses. Such disorders may be caused by long-term exposure to the causes of them during a long process or suddenly caused by a major impact on a part of the musculoskeletal system. These injuries are often multifactorial phenomena.

According to the definition, musculoskeletal disorders include muscle disorders, peripheral nerves, joints, bones, ligaments and blood vessels, resulting in stress. Repetition over time or from an instantaneous or acute trauma and has symptoms such as discomfort, pain, fatigue, dryness, swelling, limited range of motion, numbness and tingling.

On the other hand WRMSDS are a grouping of related injuries sometimes referred to as "ergonomic injuries." WRMSDS generally occur when the worker uses muscles, tendons, and ligaments to perform tasks in awkward positions or in frequent activities that, over time, create pain and injury.

Risk factors for work-related musculoskeletal disorders can be generally categorized into four categories: physical or biomechanical factors related to work, work-related organizational or psychosocial factors, individual factors and factors related to social content. The main physical risk factors of work-related musculoskeletal injuries are: manual material handling (MMH), force, contact pressure, repetitive movements, vibration, undesirable static postures and improper organization of work. Exposure to such factors has adverse effects on the body of the individual. Musculoskeletal disorders begin with feelings of fatigue and pain and are advanced towards a disease in which the movement of the limbs is restricted or muscle strength decreases. Studies in the UK have shown that 55% of occupational diseases in this country are related to musculoskeletal disorders.

Musculoskeletal disorders are the main source of disability and related costs in Iran. According to the existing statistics, nearly 48% of work-related diseases are cumulative injuries caused by physical or mechanical factors and are themselves a form of musculoskeletal discomfort. These disorders can be synonymous with CTDs (i.e. cumulative trauma disorders caused by physical and mechanical factors over time).

Mental workload and WRMSDS

In workplaces, if the physical and mental abilities of individuals are not in accordance with their job needs, it can have various negative consequences such as increasing dissatisfaction and job absence, creating stress, reducing physical ability, fatigue and reducing job returns. One of the most important negative consequences is increased incidence of work-related musculoskeletal disorders.

One of the effective cognitive factors in occupational injuries and accidents is the disproportionate mental workload of the individual with his or her abilities and limitations. Workload has complex and multidimensional concepts, but it is usually in the form of costs that are imposed on the individual in order to achieve a specific skill to perform a task with its special requirements. Simply put, mental workload is the amount of effort that the mind makes while on duty and is essentially related to one's mental abilities and how information is received and processed and ultimately leads to decisions and actions.

At the time of work, mental workload is determined according to the needs of the job, the conditions under which the work is performed, the skills, behaviors and perceptions of the individual. The needs of a job may include physical or mental actions, and the impact of these needs depends on the individual's ability to perform his or her duty. Mental workload of work makes it easier to affect physical and mental factors in musculoskeletal disorders. Previous studies have shown that with increasing workload index, stress and job stress, the risk of musculoskeletal disorders increases in people.

Lifestyle and WRMSDS

One of the most important and influential factors in the prevalence of musculoskeletal disorders and its disability in workplaces is the individual's lifestyle. Lifestyle is a set of habits and activities that a person performs during their daily life. The World Health Organization (WHO) considers lifestyle as specific and definable patterns that result from the interaction between one's characteristics, the interaction between social relations and environmental and socio-economic situations. Previous studies have shown that factors involved in lifestyle such as smoking, overweight, nutritional habits, sleep, stress and sedentary lifestyles are effective factors in causing chronic diseases such as musculoskeletal disorders and lifestyle modification can be an effective step to reduce the prevalence of these disorders in workplaces.

In most industrial countries, WRMSDS are very common and are considered as one of the most common, debilitating and costly disorders and impose many losses on individuals and societies every year in the field of health and economy. It has been found that about 33% of work absences in developed and developing countries were due to WRMSDS.

About 60-80% of the population of Western countries have experienced some of these disorders during their lifetime, and about 30% of the population worldwide has also been affected by low back pain (LBP) each month. The consequences of low back pain in patients are very important and include the onset of psychological problems such as depression, burnout and also one of the main causes of absenteeism and subsequent economic problems. Therefore, ergonomic problems are considered as a fundamental problem for society.

Work-Related Musculoskeletal Disorders & Ergonomics

In 1997, the Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH) released a review of evidence for work-related MSDs. Examples of work conditions that may lead to WMSD include routine lifting of heavy objects, daily exposure to whole body vibration, routine overhead work, work with the neck in chronic flexion position, or performing repetitive forceful tasks. This report identified positive evidence for relationships between work conditions and MSDs of the neck, shoulder, elbow, hand and wrist, and back.

The Bureau of Labor Statistics of the Department of Labor defines MSDs as musculoskeletal system and connective tissue diseases and disorders when the event or exposure leading to the case is bodily reaction (e.g., bending, climbing, crawling, reaching, twisting), overexertion, or repetitive motion. MSDs do not include disorders caused by slips, trips, falls, or similar incidents. Examples of MSDs include:

- Sprains, strains, and tears
- Back pain

- Carpal tunnel syndrome

Musculoskeletal disorders are associated with high costs to employers such as absenteeism, lost productivity, and increased health care, disability, and worker's compensation costs. MSD cases are more severe than the average nonfatal injury or illness.

- In 2001, MSDs involved a median of 8 days away from work compared with 6 days for all nonfatal injury and illness cases (e.g., hearing loss, occupational skin diseases such as dermatitis, eczema, or rash)2
  - Three age groups (25–34 year olds, 35–44 year olds, and 45–54 year olds) accounted for 79% of cases
  - More male than female workers were affected, as were more white, non-Hispanic workers
  - Operators, fabricators, and laborers; and persons in technical, sales, and administrative support occupations accounted for 58% of the MSD cases
  - The manufacturing and services industry sectors together accounted for about half of all MSD cases
- Musculoskeletal disorders account for nearly 70 million physician office visits in the United States annually, and an estimated 130 million total health care encounters including outpatient, hospital, and emergency room visits
- In 1999, nearly 1 million people took time away from work to treat and recover from work-related musculoskeletal pain or impairment of function in the low back or upper extremities
- The Institute in Medicine estimates the economic burden of WMSDs as measured by compensation costs, lost wages, and lost productivity, are between $45 and $54 billion annually
- According to Liberty Mutual, the largest workers' compensation insurance provider in the United States, overexertion injuries—lifting, pushing, pulling, holding, carrying or throwing an object—cost employers $13.4 billion every year

Ergonomics process

The process of improving ergonomics systematically identifies the risks in this field and implements the engineering and management criteria needed to control or reduce their risk.

The ergonomic improvement process generally consists of three main steps:

Risk Assessment

Ergonomic evaluation is one of the main elements of ergonomic management process. You can never improve ergonomics without effectively evaluating jobs for risk factors, such as musculoskeletal disorders.

Improvement Planning

The main goal of the ergonomics management process is to make changes to your workplace that reduce the risk of ergonomic disorders. Making large-scale changes requires proper planning, including prioritizing jobs requiring improvement, identifying ideas for improvement and justifying the cost of implementing them, or estimating the cost-benefit parameter.

Measuring Progress

Measurement is an important component to the success of any improvement process. In effective ergonomics management programs, progress is constantly measured.

Ergonomics Goals

Focusing on the interaction between humans and other components of the system, the main goal of ergonomics is to reduce human error, increase productivity, improves safety and comfort.

Advantages of Ergonomics

It is clear that ergonomics benefits us if it is right. So when we talk about the advantages of ergonomics, we mean good ergonomics. Ergonomics reduces costs, increases productivity, increases quality, employee participation and culture of ergonomics and safety at work, and also affects accuracy, health and life.

One of the most important advantages of ergonomics is improving and increasing the quality of communication. If you know how to do something without having to train, you can do things faster by relying on your inner sense.

The goal of ergonomics is to increase productivity. In order to increase productivity, tasks and procedures should be visibly understandable and therefore easy to perform. Transparent communication between the user and what the user uses increases accuracy, and that means performing tasks more efficiently.

Here, communication, speaking, or any use of words is not meant to be aware of how a product, structure or tool is used according to its physical nature and shape and form. For example, when you want to work with a hammer, which head do you hold it from? If you can use tools correctly without reading help or descriptions, that means the tools have the right ergonomic connection.

A bad ergonomics can also be a guide to creating a good ergonomics. Most of the time, your inner sense tells you that somewhere is limping, because the layout and design available don't match what you expect and what you think is right. The more complex the product, the more work is needed to ensure the right connections are created.

Management of ergonomic hazards in the workplace

Considering the knowledge of risk and risk definitions, ergonomic hazards can also be investigated in the form of those definitions. The first step is to know what ergonomic problems exist in the workplace. To achieve this, it is enough to ask the manager of industrial unit and a professional health expert to provide and report to you with careful investigations of ergonomic problems and hazards.

A professional health expert should take ergonomic risks such as other hazards during the process and stages of risk control i.e. 1- ergonomic hazard identification, 2- risk assessment, 3- control plan, 4- monitoring and follow-up of control programs.

Risk identification, risk assessment, risk control and monitoring should be on the agenda continuously. We know that each person has an abilities according to physical, and physiological characteristics, a person may have high physical and muscular strength, but his intellectual, mental and skill abilities are low. On the contrary, individual physical ability may be low and have high intellectual, psychological and skill capabilities. On the other hand, each job has its own needs.

Some occupations require workers with high physical and muscular abilities. Therefore, for this type of work, workers with high physical and muscular strength should be used. Workers of rubber, construction, mines, cargo carriers, etc. are examples of these occupations. In contrast, there are occupations that require intellectual, psychological and skillful capabilities, control room operators, pilots and all operators who work with multiple display devices to receive and process information are examples of these jobs.

Obviously, increasing productivity, efficiency, reducing errors, reducing complications and ergonomic injuries requires appropriate adaptation between work requirements and workers' abilities. In other words, ergonomic interventions are needed. Ergonomic interventions include all changes and measures that improve the adaptation between work requirements and workers' abilities. Usually, interventions fall into two areas of total hardware measures (elimination, replacement and engineering control) and software measures (management and executive, training and use of personal protective devices).

Nowadays, paying attention to ergonomic principles by focusing on all its dimensions in workplaces in order to improve people's health and productivity of the organization is very important. Physical ergonomics is one of the important dimensions of ergonomics on which many studies and evaluations have been conducted. Previous studies have shown that one-dimensional assessments in the field of ergonomics (physical ergonomics) are not effective and effective studies in this field require comprehensive attention to all aspects of ergonomics (physical, environmental, cognitive and organization) with a comprehensive approach focusing on continuous improvement cycles and resilience engineering.

Therefore, considering the importance of this issue, increasing the prevalence of ergonomic disorders in different industries and organizations, lack of similar evaluation models, the essential role of ergonomics in improving the health of employees and increasing productivity, "comprehensive model of ergonomics management in the workplace" was developed and implemented for the first time in the Iran in a power plant equipment industry.

The main purpose of this book is to present an ergonomic management model with the approach of assessing the most important risk factors in three areas of physical, environmental and cognitive ergonomics in order to reduce the risk levels of ergonomic disorders and promote the health of employees.

Chapter 2.

Literature Review

A review of the most important related studies

1) A study conducted by Maria - Elena Boatc et al. in 2014 under the title of "Approaches proposed by various organizations to perform effective ergonomic interventions" and the findings showed that the main objective of organizations in performing ergonomic interventions includes two key issues: including reducing human energy consumption (to prevent increased energy consumption) and increasing efficiency, effectiveness and productivity of human resources in work processes. The proposed communication model presented in this study consists of four main elements: management support, sufficient scientific background, evaluation, and diagnosis and participation. The process of this ergonomic evaluation and intervention model is presented in Fig.2.

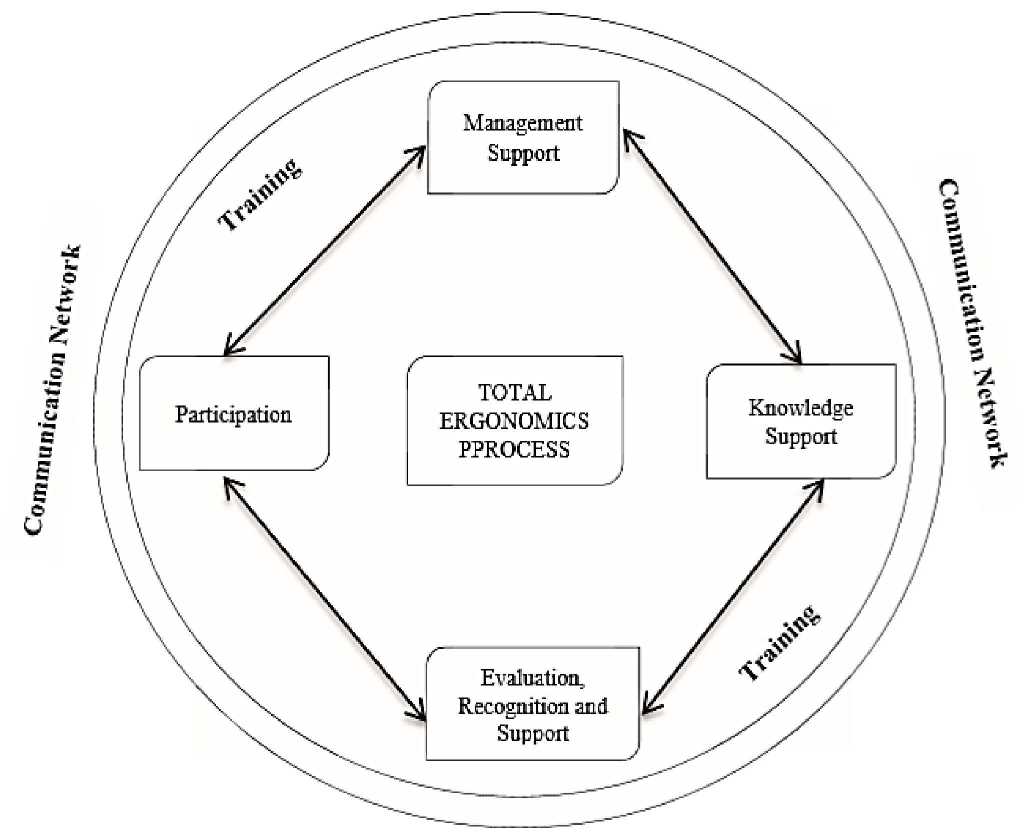


Figure 2 – Ergonomics evaluation and interventions model

2) A study conducted by Priscila Rodrigues Fernandes et al. was conducted under the title of "Ergonomics Management with An Action Approach" in 2015. The findings of this study showed that different organizations without using ergonomic risk assessment indicators using active or proactive approach, do not have a good prediction of ergonomic risk factors and thus will be

susceptible to a variety of related injuries. In this study, a 9-member team was established with the participation of engineering department in order to formulate and organize an ergonomic action model. Based on the evaluations, all the risk factors affecting ergonomic problems were identified and evaluated. Then, the principles of resilience engineering (training, responding, monitoring and anticipation) were used to manage and monitor the ergonomic process and create composite indicators. Resilience engineering is the ability to reduce or prevent the adverse effects of various events. Accordingly, organizations should be able to have four skills: learning ability, reaction ability, continuous monitoring ability and predictive ability. Finally, it was found that ergonomics management programs needed an proactive approach so that they could become a dynamic and efficient cycle at the same time as technology progressed. This system can improve the quality of work life of personnel, reduce the cost of treatment and work absences and ultimately lead to increased productivity. Also, using the general principles of resilience engineering can instill a preventive approach to the ergonomics management cycle.

The different phases of this study are presented below:

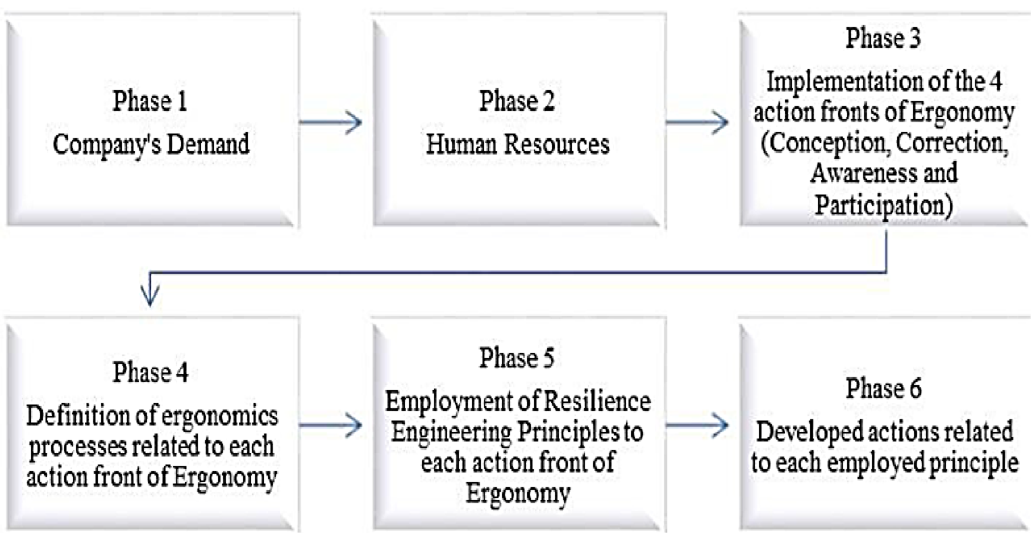


Figure 3 – Different phases of ergonomics management

3) The study conducted by Mohammad Fam et al. proposed a general framework for developing an ergonomic management system in critical systems such as power plants. This study was conducted in the control room of a thermal power plant in Iran. In the first step, the general framework was created and then implemented. The results showed that using the proposed model

can improve ergonomic conditions in similar workplaces. The proposed model flowchart is presented below:

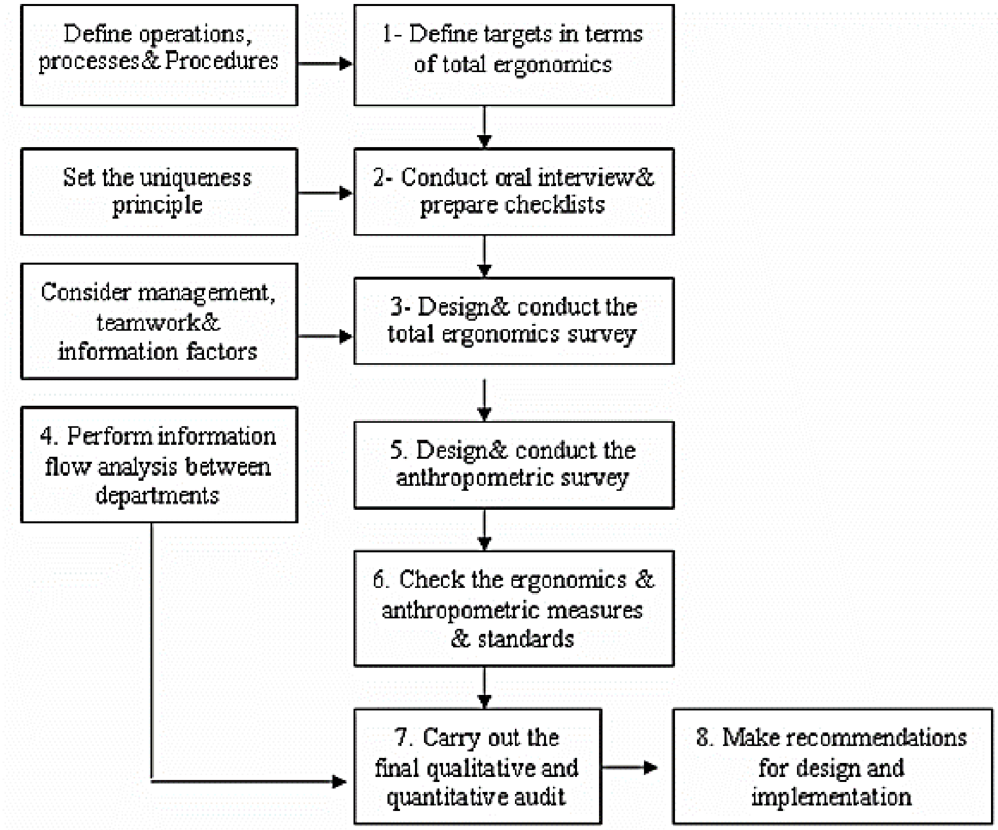
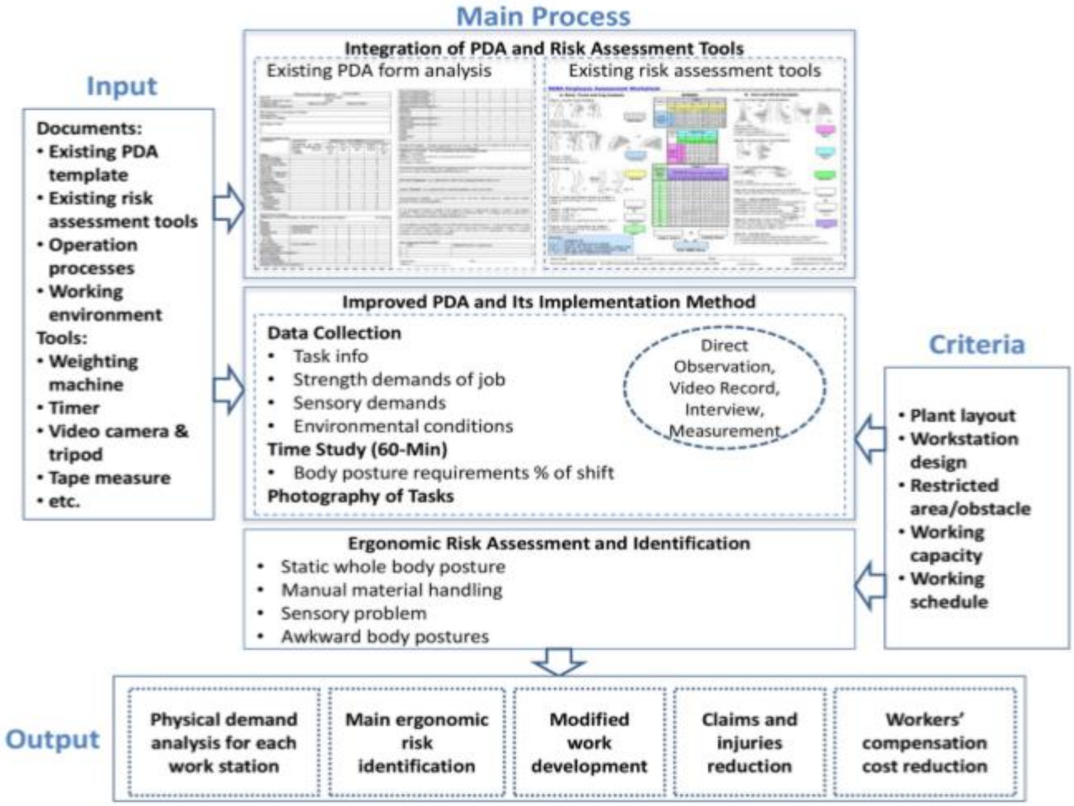


Figure 4 – Executive steps of the ergonomic evaluation model

Also, the findings of this study revealed that workload, job stress and time pressure are important parameters in the proposed ergonomic model.

4) A study conducted by Xinming Li et al. entitled "Improved context of physical needs analysis based on ergonomic risk assessment tools in the manufacturing industry" in 2019 showed that due to the high physical needs of work in the industries, the use of risk assessment methods with an proactive approach is of great importance. Physical Demand Analysis (PDA) is a common tool for assessing risks in three areas of physical, cognitive and environmental dimensions. During this study, the required inputs and the most important outputs of this tool in the application of industries were investigated.

The process of this method is presented below.



5) A study conducted by Sadeghi-Yarandi et al. under the title of "Investigating the relationship between physical, cognitive and psychosocial risk factors with the prevalence of musculoskeletal disorders and its disabilities among flight protection staff in Iran". In this study, among 316 flight protection personnel in 2020, the results showed that 68% had musculoskeletal disorders in at least one of their limbs and 32% of the subjects did not have musculoskeletal disorders. It was found that there was a significant relationship between age, work experience, body mass index, gender and education level from personal characteristics, components of health responsibility, stress management, exercise and nutrition from lifestyle, physical job demands component of job stress and physical workload, time pressure and effort from mental workload and prevalence of musculoskeletal disorders (p-value <0.05). Therefore, corrective measures are necessary to reduce the prevalence of these disorders by eliminating and controlling the levels of individual, physical and psychosocial risk factors.

6) A study was conducted on the effectiveness of ergonomic interventions by Smith et al. entitled "Evaluation of ergonomic interventions in dentists' workplaces". In this study, alternative methods

for observing teeth during simulated dental procedures were investigated. These methods allowed participants to imagine states that require less neck bending than standard direct vision. One option used a camcorder and a monitor to view the mouth, the other used 90-degree prismatic glasses. This study was conducted in two parts: (1) Novice participants who perform a targeted task. (2) Dental hygienists who do the scaling on the oral model. The status of deployment and mental comprehension were evaluated in parts 1 and 2. Muscle activity and function were also evaluated in part 1. It was found that alternative methods significantly reduce muscle activity, neck bending and discomfort compared to direct view. Previously, recommendations to reduce the exposure of ergonomic factors of dental professionals emphasized on reducing the time spent doing dental procedures. This study shows that ergonomic interventions offer other options to reduce exposure to ergonomic hazards.

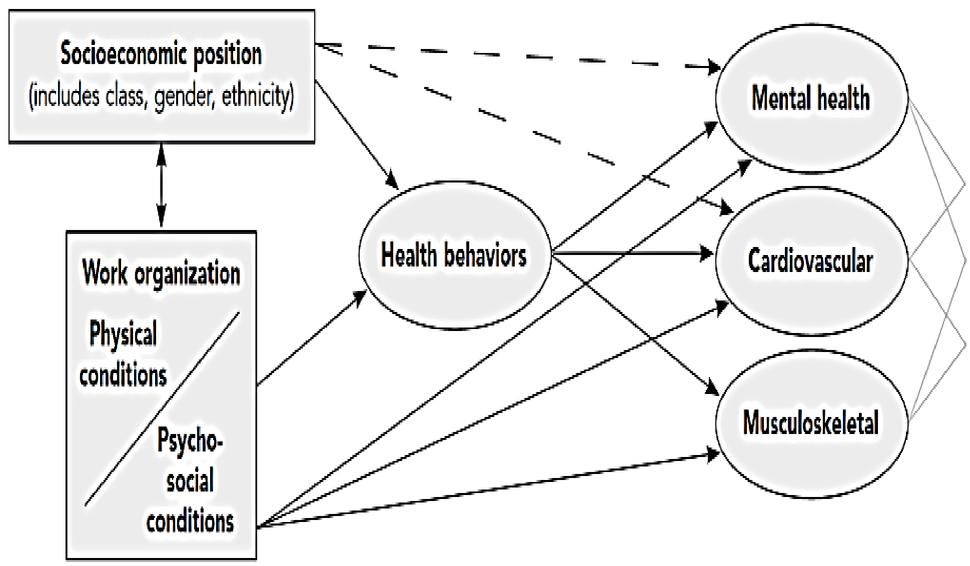
7) A study conducted by Bergqvist et al. entitled "Musculoskeletal Disorders among Screen Monitoring Workers: Individual, Ergonomic and Organizational Factors". In this study, a number of individual, ergonomic and organizational factors affecting the incidence of musculoskeletal disorders in a group of 260 visual display terminal personnel were investigated. In this cross-sectional study, medical information and workplace inspection as well as questionnaires were used. The results were used for multivariate analysis to find major factors associated with various upper body muscle problems. Individual risk factors include age, sex, having children for female personnel, wearing glasses, smoking and gastric stress reactions. Organizational variables include the importance of flexibility of work-rest programs, interpersonal communication and overtime. Also, the most important ergonomic variables included things such as static work situation, hand position during work, use of arm support or arm head, frequent hand and keyboard movements, or vertical position of the display.

8) A study conducted by Oxenburg entitled "cost-benefit analysis of ergonomic programs". In this study, a cost and benefit analysis method for calculating the cost of employment is described. The purpose of the analysis is to portray financial bringing, health benefits, productivity and quality resulting from improved ergonomic working conditions. This analysis can be used to measure financial benefits after the completion of changes in working conditions or can be used to demonstrate the potential value of the proposed cost (improving working conditions). It may also use profit and benefit analysis as a sensitivity analysis to identify areas with high labor costs (e.g.

high-cost work environments) and/or loss of productivity (e.g. poor quality of service or product) and use its results to improve working conditions.

9) A study by Yazdani et al. entitled "How compatible are participatory ergonomics programs with occupational health and safety management systems?" In this study, 21 OHSMS elements were extracted using occupational health and safety assessment series (OHSAS 18001). In order to define the participatory ergonomics, 20 articles that received the most citations about participatory ergonomics were identified and the content of each of the OHSAS 18001 elements was extracted. The findings showed that the participatory ergonomics literature provided a considerable amount of detail about five elements: (1) Risk identification, risk assessment and determination of controls, (2) resources, roles, responsibility, accountability and authority, (3) competence, education and awareness, (4) participation and counseling and (5) measurement and monitoring of performance. However, of the 21 OHSAS elements, the participatory ergonomic literature was unrelated to 8 elements and provided few details about the other 8 elements. Finally, in this study, it was found that participatory ergonomic literature was not related to many of the elements described in OHSMS and in many cases the language used was different. This may affect the effectiveness and sustainability of participatory ergonomics initiatives within organizations. It is predicted that paying attention to the approaches and language used in participatory ergonomics within the frameworks of the management system can be more effective and sustainable in advancing interventional activities in reducing the prevalence of ergonomic disorders.

10) A study conducted by Punnett et al. entitled "A Conceptual Framework for Integration of Health Promotion Programs and Occupational Ergonomics at Work". The results of the study revealed that musculoskeletal, cardiovascular and mental health are all associated with physical and psychosocial working conditions as well as individual health behaviors. An integrated approach to workplace health promotion programs should include paying attention to all aspects of the workplace, especially in light of recent findings that the ILO has studied the term lifestyle or health behaviors. Macro ergonomics provides a framework for improving the physical and organizational characteristics of the work, as well as for empowering working people. The New England Center for Workplace Health Promotion (CPH - New) is a research-practical effort that examines the effectiveness of workplace programs and combines occupational safety and ergonomics programs with health promotion and emphasizes the participation of organizations in both cases. The proposed model of this study is presented below (Fig. 5).



[a]Health behaviors include tobacco and alcohol consumption, aerobic exercise, nutrition, and sleep.

[b]Not shown in the diagram: mediators of other links from socioeconomic status to health or the reciprocal effects of health on socioeconomic position, working conditions, or health behaviors.

Figure 5 – The relationship between working conditions, health behavior and socioeconomic status

Chapter 3

Introducing the TUGA Ergonomic Management and Analysis Model (TEMA)

The purpose of the ergonomic management and evaluation model

The aim of this model is to evaluate the ergonomic index by focusing on three physical, environmental and cognitive components and reducing the levels of ergonomic disorders to the lowest possible level and increasing productivity in different industries and organizations.

What is done in the TUGA Ergonomic Management and Analysis Model (TEMA[1]):

1. Performing a Tabular Tasks Analysis (TTA) of Existing Occupations
2. Ergonomic hazard Identification (EHI) in each of the existing occupational tasks
3. Evaluation and estimation of ergonomic index for each of the job tasks
4. Determination of control measures in accordance with the results in the evaluation phase
5. Evaluation of ergonomics economy and estimation of cost-benefit parameter
6. Implementation of accepted control measures
7. Continuous and regular monitoring of control measures
8. Evaluation of the effectiveness of control measures

The main structure of the TEMA model

In general, the first step of the ergonomics management algorithm in the workplace is to know what ergonomic risk factors exist in each task. For this purpose, different sources such as checklists, results of examinations and evaluations, etc. can be used. After this step, different tools can be used for each risk factor (in fact, one of the most important innovations in the proposed model is to develop a new and comprehensive method of ergonomic evaluation for different jobs and assign a score and level of ergonomic risk to each of the existing tasks and occupations with a focus on different dimensions of ergonomics (physical, environmental and cognitive).

In the next step, the evaluated values are evaluated and according to the sensitivity and tolerance level of the organization, ergonomic risk levels are determined and evaluated. Then, the control measures are planned and before the implementation of control measures, the ergonomics economy assessment is done in order to determine the values of cost-benefit parameter.

After implementing the control measures, the ergonomic index of the tasks was evaluated again to determine the effectiveness of the measures. It should be noted that all these measures are carried out continuously relying on resilience engineering theories, Kaizen continuous improvement approach, and Deming cycle (PDCA).

[1] TUGA Ergonomic Management and Analysis Model

These control measures are also implemented in three levels of technical-engineering, managerial-executive and personal protection equipment, respectively. An example of management algorithm and ergonomic evaluation is given below.

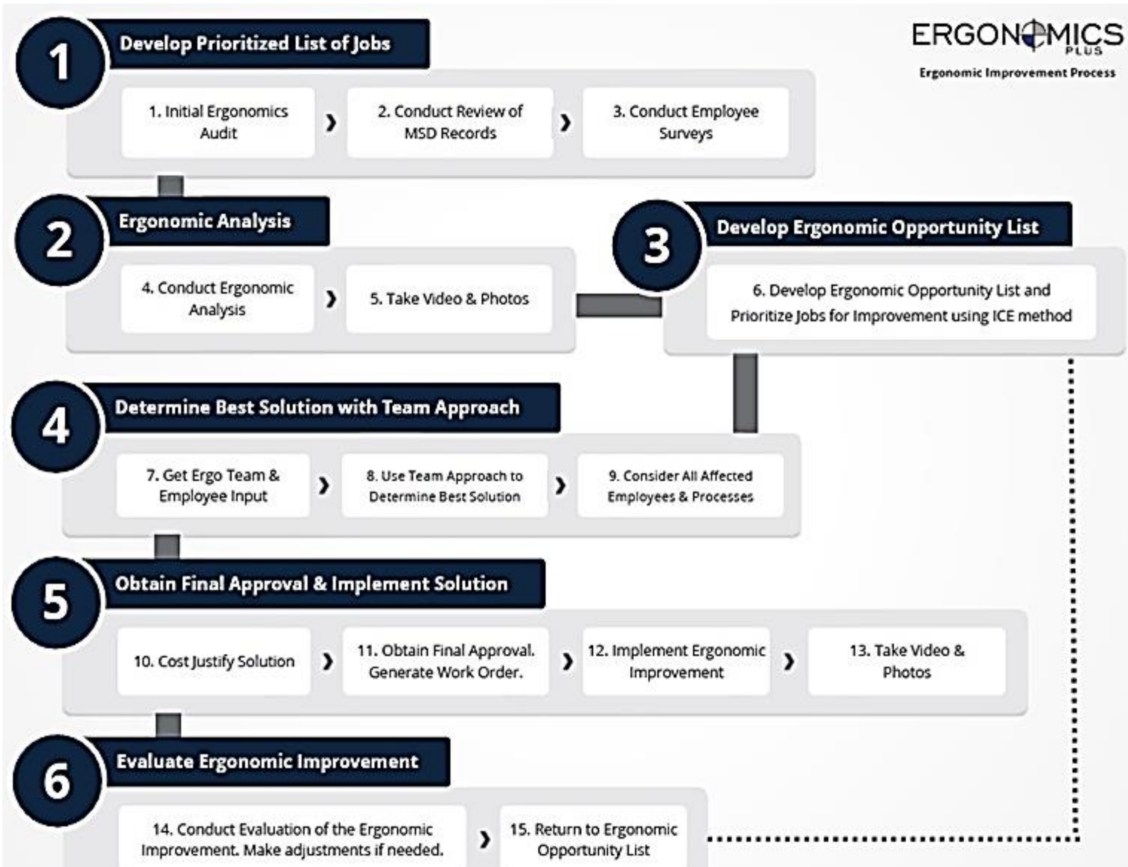


Figure 6 – An example of the ergonomics management model

Resilience Engineering Concept

Resiliency components of a system

The components of a system's resilience in the event of a disturbance are:

Before the accident:

1. Situational alertness: Awareness of the system situation in the past, present and future (extensive system of monitoring, protection and control)
2. Preparedness: Preparation for strong gray and black events
3. Endurance: Endurance against known events

During the accident:

1. Adaptability: Adapt to the new network status
2. Durability (tolerance): The system's ability to adjust the accident

After the accident

1. Recovery and self-recovery: Return to normal operation mode, detect and locate and fix errors and automatic recovery
2. Speed of action: High speed to return to normal situation

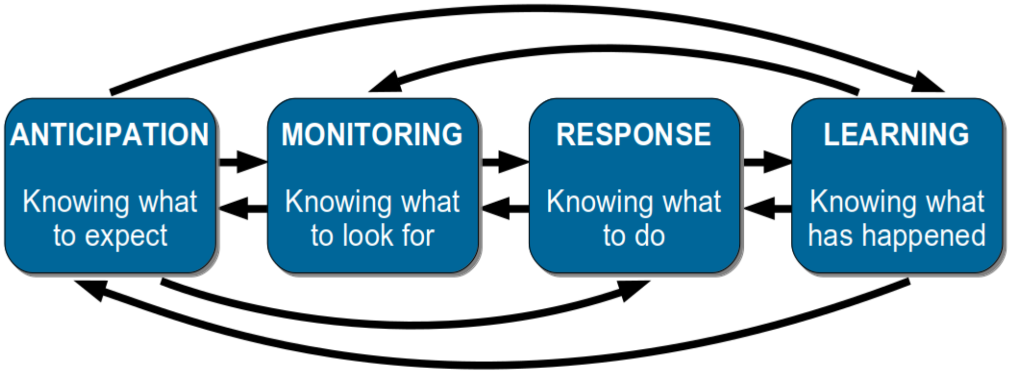


Figure 7 – Resilience Engineering Process

Measuring the resilience of a system

In order to evaluate resilience, quantitative indicators should be defined. The following figure displays the system performance indicator regarding the system's supplied load in time (e.g. for example).

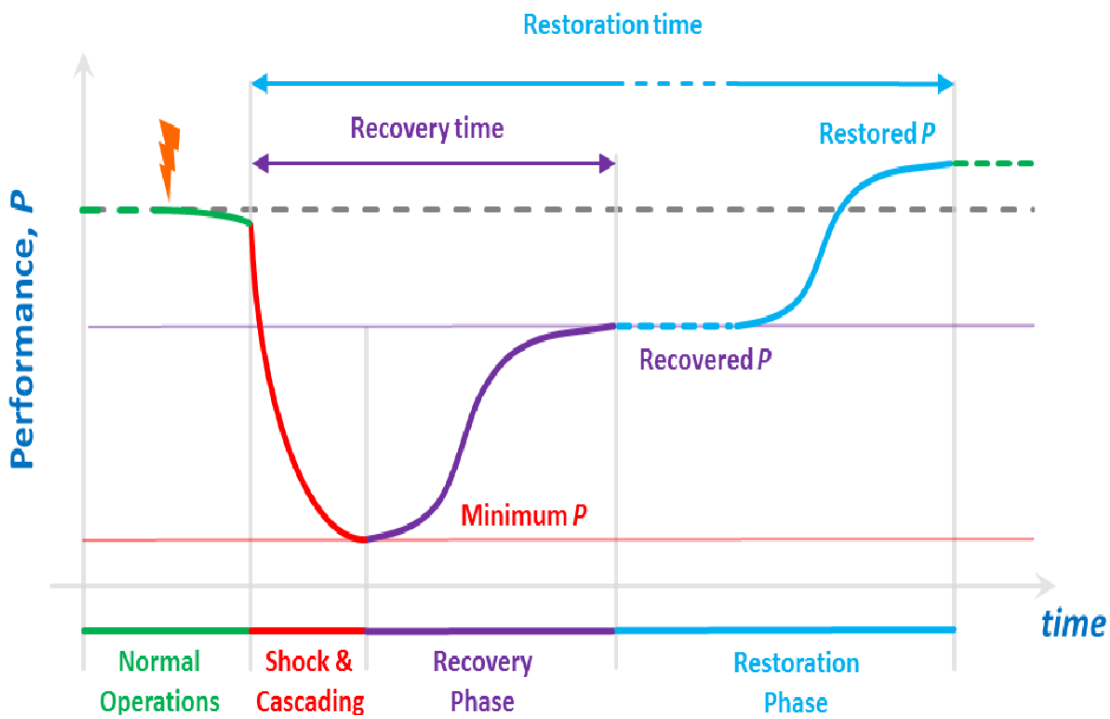


Figure 8- System performance indicator regarding the system's supplied load by time

As is evident in the figure, the system's performance does not drop quickly after the beginning of the accident (t0) due to its endurance. This step can be called prevent. The duration of this phase depends on the state alertness and strength of the network. Naturally, the longer the prevention period, the higher the reliability. This increase in time depends a lot on the design stage and the accuracy in doing it.

After td time, the system performance drops. The durability phase begins from this moment and continues until the system remains at maximum drop (t min).

The recovery phase starts right from the time the system's performance improves and continues until the system returns to a stable state before the incident occurs. Recovery time can be considered as an indicator to measure the quality of system recovery. Less time indicates the resilience of the system.

An engineering system is usually designed in such a way that it has the necessary resilence against ordinary accidents and its performance in such situations is not easily affected. But at the same time, this system must also have sufficient resilience to adapt itself to a severe disturbance without losing its function and quickly recover itself after the disturbance has been resolved.

Resilience in Ergonomics

It should be noted that in the present model, the principles of resilience engineering (training, responding, monitoring and anticipation) have been used to manage and monitor the ergonomic management process and create composite indicators. Resilience engineering is actually the system ability to reduce or prevent the adverse effects of various events. The focus of this approach is mainly on concepts such as the ability to discover hazards, predict and prevent.

Accordingly, the organization should be able to learn four skills, reaction, continuous monitoring and prediction. Ergonomics management programs require an actionable approach so that they can become a dynamic and efficient cycle as technology advances. This system can improve the quality of work life of personnel, reduce the cost of treatment and work absences and ultimately lead to increased productivity. Also, using the general principles of resilience engineering can induce a preventive and pro-active approach to the ergonomics management cycle.

The following six indicators show a resilient system:

Management Commitment: Understanding and committing to the health of individuals is a value for the organization.

Creating a Culture of Reports: Stimulating the communications in the organization in order to prepare reports.

Learning: Daily work analysis without ignoring lessons from events.

Awareness: All personnel should be aware of the current situation and the system's resistance to the actualization of potential ergonomic hazards.

Preparation: The organization should anticipate all the risks related to human performance in human-machine systems and formulate a way to deal with them.

Flexibility: The ability of the system or organization to deal with new and complex problems in order to increase the organization's ability to resist the risks without disrupting the main efficiency.

Finally, the phases of ergonomic management with the resilience engineering approach can include:

Design Ergonomics: Including the use of ergonomic principles in designing and implementing ergonomic interventions.

Corrections Ergonomics: Includes steps to identify ergonomic hazards, evaluation to reduce ergonomic disorders (such as the prevalence of musculoskeletal disorders).

Awareness Ergonomics: Includes all educational programs in the field of ergonomics to institutionalize participatory ergonomic culture.

Participation Ergonomics: Using the science and experiences of personnel to correct and improve ergonomic conditions of the workplace.

Ergonomics management with macro approach has paid attention to all aspects of ergonomics in the organization, has an action approach and does not act solely on the basis of previous reports. These cases allow the organization to identify, prioritize and implement appropriate control measures before realizing potential ergonomic risks.

In the present model, the principles of resilience engineering (lraining, responding, monitoring and anticipation) have been used to manage and monitor the ergonomic management process and create composite indicators.

Kaizen concept

Kaizen's strategy is the most important concept of Japanese management and the key to the country's competitive success. Kaizen means continuous improvement with the participation of everyone in a company or organization, Kaizen is a public duty. Kaizen is a trend-oriented thinking system versus an innovative and result-oriented thinking system.

Kaizen's philosophy is based on the principle that human lifestyles, including career life, social life and personal life, must be continuously improved. Kaizen's culture and its interaction between different layers and social organizations in Japan has led the factory to become a university, and the university to the factory, the worker learns from the manager and the manager benefits from the ideas of the worker, the researcher wears a work clothes and comes to the production scene, and the activists of the production scenes think about improving their work and turn to research. Kaizen's strategy message is summarized in this sentence: Not a single day should be spent without making some kind of improvement in one of the parts of life, organization or company.

Kaizen is a two-word combination of a Japanese concept that defines a shift toward betterment or continuous and gradual improvement. In fact, Kaizen is based on the philosophy that in order to make improvements in organizations, we do not need to look for explosive or sudden changes, but any kind of improvement or modification, provided that it is continuous and continuous, will bring about productivity improvement in organizations. Japan used this method after World War II. This method helped Japan to return to power in the industry and reintroduce its businesses. In Japan, everyone knows what Kaizen is, and they use it on whatever side they are. They benefit from this method even in their personal lives. In general, you need to consider three key issues to use this method:

Muda: Delete activities that are not worth the organization. These activities are a waste.

Muri: Similar activities are performed in parallel by multiple sections, combining them together.

Mura: Add activities that create added value and upgrade it to the system.

One of the famous companies in the application of kaizen is Toyota. In 1999, seven thousand employees of this company presented 75 thousand small and big suggestions, more than half of them were implemented.

Kaizen's steps are:

1. Select the area that is aimed at Kaizen.
2. Form a group for Kaizen.
3. Collect the required data about what is being done now and the final goal.
4. Check the tools and facilities you have to implement kaizen stages and continuous growth.
5. Identify the activities of Moda, Murray and Mora and arrange a suitable strategy for each of them.
6. Write down the group's suggested solutions and choose more practical solutions.

7. By obtaining approval from the up-hand officer, implement the solution and review its changes.
8. If the solution works, turn it into a trend in your organization. If it does not work, go to the next solution.

Kaizen Management Model

As we come from high levels of management to lower levels of organization, the tasks of the category of improvement are reduced and instead added to the tasks that improve the maintenance aspect. What we understand from this diagram is that managers of higher levels of the organization should always spend much of their time improving the organization and leaving the current affairs that are maintenance to the lower levels. Therefore, from Kaizen's point of view, employees of an organization should always think about improving and maintaining the achievements of improvement in their organization, and managers of the organization should also be looking forward to receiving constructive opinions of employees in reducing defects and improving the quality of their services or products.

The ability of an organization to respond quickly to market needs is the guarantor of its survival and the use of Kaizen, Balm and treatment for many problems of organizations will be on the path to success. Also, many of the problems facing senior managers of the organization today are resolved with the help of Kaizen and by the lower ranks workforce, and senior managers can engage in strategic plans.

In the design of the kaizen system and for its effective implementation, one should have a comprehensive view of all operational factors, and not paying enough attention to the factors or neglecting some of them causes failure in the establishment of the kaizen system. It should also be noted that kaizen activities should be determined according to the activity and working methods of your organization, because each part of a company or organization, depending on the type of task and activity, which is determined and implemented in line with the overall goals of the organization, should be able to Improve and increase the productivity of your unit by understanding the importance of kaizen in relation to its implementation in the aforementioned ways and announce your goals, plans and actions in the main kaizen committee of the organization in order to share experiences and also determine the progress.

In the proposed model, special attention has been paid to the kaizen concept using steps such as regular monitoring and periodic evaluations to ensure the effectiveness of the implementation of the model .

The concept of Deming cycle

Medium and large organizations, and all businesses in general, need to develop and improve their businesses in any way, and this will be possible through improving processes. Various tools and methods have been designed and presented in this regard, one of the best and most effective of which is the Deming cycle model or PDCA.

This cycle is also called a continuous improvement cycle in a simpler language that can be used to improve organizational processes. Using this cycle of continuous improvement, higher growth and optimization can be achieved in different organizational sectors.

This method is presented by Dr. Edward Deming. In fact, this cycle is an effective model in all processes and despite simplicity, it is very efficient. In this way, organizations can make a serious change in their processes and benefit from them in favor of organizational productivity.

The PDCA cycle operates in a circular and rotating manner and affects various parts of the organization, including the development of new products, increasing sales, increasing customer satisfaction, improving the quality and implementation of any scientific and executive projects.

PDCA is a combination of Plan, Do, Check and Act, which means planning, doing, checking and operating, respectively. In fact, this cycle is a four-step work cycle that is used to make changes and improve processes in businesses and organizations.

PDCA Cycle Application

This cycle can be used in various levels to promote processes and improve them. Of course, when we are looking for gradual improvements in organizations, this cycle will have its best performance. Also, when we are going to start a new process, the PDCA will provide the right tools.

Improving sales and increasing customer satisfaction, changing the necessary methods and improvements in processes are also among the things that make the use of Deming model meaningful.

In other words, when planning, collecting data, small-scale analysis, reviewing priorities, rooting problems and finally to perform any form of gradual changes, it is needed to use this cycle.

Deming cycle stages

1- Initial planning

The first stage and the most important of the cycle involves planning. Remember that achieving defined organizational goals requires careful and targeted planning. In other words, setting goals and predicting ways to achieve it will lead to some kind of commitment to carry out certain activities to achieve that goal.

2- Performing (doing)

In order to ensure the acceptable results of the planning that have been done in the previous stage, the implementation of the minimum experimental and analytical results will be required. In this way, problems and defects can also be shown and can be resolved in the operational phase. As a result, necessary modifications and restorations are obtained for larger modules.

3- Checking

One of the important tasks that we should pay attention to in the realization of planning will be continuous performance measurement. In the process of control and investigation, we will compare the results with the specified objectives and understand their shortcomings. In this way, reforms and changes can be made if needed.

4. Acting

If all that was true in previous stages, such as reviews and experiments, is now time to take action and implement plans. Considering the nature of the work, the most appropriate way of implementing the plan should be chosen to achieve the desired result.

How does the Deming cycle improve processes?

If the mentioned steps are carried out to improve a process and there is no change on a small scale and no positive effect is observed, it should not be extended to other processes or the same process on a large scale. Therefore, it is possible to choose another design and go through the four stages for it.

Only when this cycle should be extended on a large scale or to larger work processes, when we do the four steps on a small scale, the result is completely successful. Therefore, based on the lessons learned and experiments conducted in the cycle, positive changes in business can be operationalized, expanded and applied on a larger scale.

It can be said that PDCA has a structure for overall strategic planning of the organization, experience and analysis of needs, designing programs, delivering and setting small and large goals, evaluating employees and providing better customer service, support services, etc.

This cycle, can continuously examine all small and large sectors on a permanent basis, is an efficient way to implement any change and evaluate the activities of the organization.

It is also suitable for starting a project due to having an improvement cycle. Because by collecting data and analyzing them in order to investigate and prioritize problems and determine the underlying causes, it leads to the best possible response and problem solving.

The basis for formulating the current model cycle is based on these principles. The use of these concepts can be an executive guarantee for education to ensure the effectiveness of various projects in the field of ergonomics and occupational health.

In the following, all concepts and theories in calculating the ergonomic index as the heart of the TEMA model (the third step of ergonomics management system) are presented.

Description of the method used in TEMA for evaluation of ergonomic index

After identifying the ergonomic hazards, evaluation of their risks is necessary. In this stage, in order to determine the measured parameters for each group of occupations, the most important parameters and indicators in each dimension of ergonomics, including physical ergonomics, environmental ergonomics and cognitive ergonomics were determined by reviewing scientific literature published in valid scientific databases as well as obtaining the opinions of experts.

In order to determine the measured indicators in each of the job subgroups, the existing jobs were divided into three general groups including office jobs, operational jobs, and support jobs. Definitions of each dimension and indicators are presented in the evaluation methods in the following.

Physical ergonomic

Generally, it focuses on biomechanical, anatomical, physiological and anthropometric characteristics of humans. This branch of ergonomics also investigates the effect of physical factors on the efficiency and performance of individuals. Participation in the design of office and industrial workplaces as well as the products and supplies used by individuals are among the projects related to this branch.

Physical ergonomics includes:

1. Biomechanics and Anthropometry
2. Work Physiology
3. Workplace Design
4. Tool Design

In this section, the most important indicators are as follows:

1. Assessment of postures during work
2. Assessment of manual material handling (MMH)
3. Prevalence, severity and disabilities due to musculoskeletal disorders
4. Muscle fatigue
5. Work physiology (determination of energy consumption in each job task based on past empirical studies)
6. Biomechanics and Anthropometry

A) Assessment of postures during work

People working in different sectors of the industry perform various tasks such as cargo handling, regulating machines, switching parts, welding, milling, periodic examination of machinery, etc. They are affected by various and undesirable postures during their work. Previous studies, each of which has been carried out on one or more of the tasks of people working in the industry, have reported the presence of these disorders in the mentioned individuals.

For example, it has been found that the main physical problems in welding and milling tasks as one of the most repeated tasks in production or maintenance jobs, including low back pain, shoulder pain, knees pain, white finger disease, carpal tunnel syndrome and reduction of muscle strength. Due to the increasing prevalence of musculoskeletal disorders and the importance of controlling these disorders in workplaces, nowadays, different methods have been developed to evaluate occupational exposure to the risk factors affecting the incidence of these disorders and each method has different factors such as different states of body deviation from natural posture, repetitive movements, force, duration and other environmental, individual, etc. risk factors. These methods are generally divided into three categories: self-report, observational, and direct measurement. One of the most commonly used methods is observational methods, due to their simplicity, flexibility and low cost of implementation.

According to the studies conducted in similar industries by authors and colleagues and evaluation of the effectiveness of different methods, during the present model, REBA method is used to evaluate the ergonomics of jobs with standing tasks, RULA method is used to evaluate the ergonomics of jobs with sitting tasks, and ROSA method is used to evaluate the ergonomics of administrative activities. It should be noted that static or dynamic job tasks will also be used as an important factor in evaluation methods.

Rapid Entire Body Assessment (REBA[1])

In this method, which is presented by McAtameny and Hignet[2], first the posture or activity to be evaluated is selected, then using the designed diagrams, the posture is assessed. Different organs are coded and the posture score of the limb is combined with the force and type of activity, and finally the overall score is the risk of musculoskeletal injuries, the priority level of corrective actions and necessity. Implementation of ergonomic intervention programs is determined, so that score 1 revealed that the risk level of waiver and corrective action are not necessary, score 2-3 revealed that the low risk level and corrective action may be necessary, score 7- 4 revealed that the moderate risk level and corrective action are necessary, score 8-10 revealed that the risk level is high, and corrective action should be taken as soon as possible, and when score is 11-15, the risk level is very high and the corrective action must be taken as soon as possible. The validity and reliability of this method have been confirmed in previous studies.

Rapid Upper Limb Assessment (RULA[3])

This method was first proposed in 1993 by McAtameny and Corlett to evaluate sitting activities. This method evaluates the physical condition, the force used and the static muscle activity of the individual. In this method, each side of the body that is worse is evaluated. In this method, in addition to posture, the force and movements are considered. The final score in this method is from 1 to 7 so that the score of 1-2 is at the corrective level of one and is acceptable, the scores of 3-4 is at level two and require further studies. The scores of 5-6 is at level 3 and mean further study and ergonomic interventions in the near future, and finally the score 7 indicates the worst posture and the fourth level and indicates the necessity of making changes and ergonomic interventions as

[1] Rapid entire body assessment
[2] Mc Atamney and Hignett
[3] Rapid Upper Limb Assessment

quickly as possible. The validity and reliability of this method have been confirmed in previous studies.

Rapid Office Strain Assessment (ROSA[1])

This method was published by Michael Sun et al. at the University of Windsor, Canada, during 2011-12 with the aim of quickly determining the risks of musculoskeletal injuries associated with administrative tasks and tasks with computers. In the last 20 years, computer work has increased dramatically, and in addition, a similar increase in the number of musculoskeletal discomforts has been reported since the beginning of computer use.

RULA method is one of the methods used to evaluate human interaction with computers in office environments. RULA method focuses more on the condition of the upper extremities of the body, and in the use of this method, the direct effect of office equipment (such as chairs, monitors, telephones, etc.) on humans is not necessarily known. Also, checklists designed to check office workstations lack the level of corrective action and on the other hand, there is no direct correlation between the results and employees' discomfort. In this method, it is possible to evaluate physical posture, office equipment and the relationship between final score and physical discomfort and providing the required level of corrective action. The validity and reliability of this method have been confirmed in previous studies.

Occupational Strain Assessment (SI-JSI)[2]

It should be mentioned that in jobs where the amount of manual activities is high and the application of intermittent manual forces is part of the job duties, the assessment and evaluation of the job strain and the torque on the joints are used as the basis for determining the biomechanical component in the selected job duties.

This technique is used to evaluate the exposure of the upper end limbs, especially the wrist and hand, to ergonomic risk factors. Wrist and hand force (IE), duration of force in each job task (DE), efforts of individuals in task (EM), wrist and hand postures during task (HWP), speed of task (SW) and total duration of task during the working day (DD) are the risk factors in this method which are merged with each other with the following relationship and finally the final score of SI Is educated.

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[1] Rapid Office Strain Assessment

[2] Job-Strain Index

SI = IE × DE × EM × HWP × SW × DD

The risk levels in this method are as follows:

1. Low risk: score <3
2. Average risk: score 3.1 - 7
3. High risk: score >7.1

The reliability within the observer and between the observers of this technique has been evaluated moderately to well and its validity has been confirmed in both longitude and cross-sectional studies.

Also, in some cases, in order to make better decisions, the following formula is used to calculate the torque of joints:

T = FR

T: Torque

F: Force

R: The distance between the force effect points to the rotation axis (joint)

Evaluation of static and dynamic occupational tasks

From the point of view of muscle mobility, work is divided into static and dynamic categories. In dynamic work, there is a change in muscle length and circulation in the muscle is better and oxygenation is better. In this case, most of the muscle force is supplied through the aerobic cycle. However, in static work, it does not change the length of the muscle and working in these conditions produces lactic acid in the muscle, because constant pressure on the muscle causes insufficient blood flow in the muscle. As a result, the anaerobic cycle is active and causes muscle fatigue. In order to further study the topic, muscle fatigue assessment tool (MFA[1]) is used in the present model.

B) Assessment of manual material handling (MMH) in related occupations

In the present model, according to the occupational analysis, MMH tasks are identified and WISHA method is used to assess the risk levels of MMH. WISHA method is a computational method based on a combination of NIOSH and HSE methods. In 2000, the Washington Department of Labor and Industry provided checklists aimed at identifying the risk of musculoskeletal disorders in the workplace. This checklist has 4 sections, one of which is related

[1] Muscle Fatigue Assessment

to the evaluation of load lifting tasks. The validity and reliability of this method have been confirmed in previous studies.

Application in jobs and workplaces: heavy load lifting activities, frequent or inappropriate.

Limitations: It does not take into account the compressive forces in each area of the body and its sole purpose is to determine the weight of the load below its limit.

Risk factors of musculoskeletal disorders: lifting force, repetitive movements, inappropriate lifting and loading conditions.

Physical wards to evaluate: waist

It should be noted that in jobs that are in addition to carrying loads, moving, pushing or pulling loads, the Snook method and related software are used to study the final score of MMH.

C) Evaluation of prevalence, severity and disabilities due to musculoskeletal disorders

In order to determine and evaluate the prevalence, severity and disabilities caused by musculoskeletal disorders in all job tasks, the Cornell Musculoskeletal Disorders Questionnaire (CMDQ[1]) is used. This questionnaire is arranged in three parts: frequency of discomfort, severity of discomfort and the effect of discomfort on work capacity and has a body map and examines 12 organs, a total of 20 areas of the body. The results of three parts of the questionnaire are multiplied by each member, the final result is a number between 0 and 90, which is the result of multiplying the repetition score (never=0, 1 to 2 times a week = 1.5, 3 to 4 times a week = 3.5, every day=5 and several times a day=10), discomfort score (3, 2 and 1) and work interference score (3, 2 and 1). In calculating the questionnaire, zero is placed instead of the missing data. The validity and reliability of this tool have been confirmed in previous studies (Cronbach's alpha: 0.986).

D) Muscle Fatigue

In this model, muscle fatigue assessment tool is used to determine muscle fatigue. Muscle fatigue assessment (MFA[2]) is known as a functional work evaluation technique developed by Rogers Williams in 1978 to describe workers' discomfort. As the duration of work increases, some workers use shortcuts and shorter ways to do their jobs faster than the standard required. Workers have also reported that they are doing their job faster to increase the time of return (recovery) after each work cycle for tired muscles.

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[1] Cornell Musculoskeletal Discomfort Questionnaire
[2] Muscle Fatigue Assessment

Since workers monitor their fatigue, it will be a desirable method that can estimate the amount of fatigue accumulated in a task. Studies of muscle physiological fatigue at different effort levels and baseline holding times provide the basis for this method. The frequency of muscular efforts determines how much return time is available between efforts. In fact, the output of this method, along with the amount of energy consumed by different jobs, is a tool for determining and deciding the duration and frequency of personnel's resting time during work shifts. The validity and reliability of this tool have been confirmed in previous studies.

E) Work Physiology

In general, any occupational activity requires the use of muscle and muscle energy. Each individual has certain and limited capabilities according to their physical, physiological and psychological characteristics. On the other hand, each job meets certain requirements. Therefore, determining the amount of energy consumed by individuals in different ways from laboratory, experimental or subjective methods in order to determine the ergonomic risk levels of different job tasks is very important.

The amount of energy consumed varies according to the type of job activity. A person doing administrative work needs 2,000 to 2,400 kcal, but an athlete or worker with heavy and varied job duties may consume 4,000 to 6,000 kcal of energy during the day. Therefore, in determining the amount of energy consumed by individuals in performing job tasks, type of activity (light, heavy and medium) and duration of activity is very important.

Energy consumption consists of thermal energy which is composed of basal metabolism and special dynamic action. Thermal energy accounts for about 50% of energy consumed in natural conditions and light works. The rest of the energy is related to displacement (mobility for essential actions), which accounts for about 30% of the energy and the rest is 20% of the work energy.

Important scales for measuring physiological stresses

1. Oxygen consumption
2. Maximum Aerobic Power
3. Heart Rate
4. Curves improve heart rate
5. Hormones (epinephrine and nor epinephrine)
6. EMG Electromyography
7. Subjective Scales

8. Available tables (based on valid experimental studies)

As physical activity increases, the amount of energy needed also increases. To provide more oxygen, more blood pumping and cardiac output are needed.

In the present model, due to economic constraints and the possibility of lack of access to laboratory instruments, determining the amount of energy consumed in different job tasks, the results of past empirical studies and related tables and equations are used and the amount of energy consumption for each of the job tasks is extracted.

Also, in this model, sampling method and systematic workload estimation (SWE[1]) are used to conduct a further study in this section and to estimate the metabolic rate. In this method, codes for 45 modes of physical activity, organs and work intensity are provided. In this section, there are 3 fixed situations (including sitting, standing and reclining), walking (slow and moderate) and high effort (walking fast, walking on a ramp, walking on a soft surface, climbing a ladder, walking with a heavy load and working too much force) that each of these situations can be studied from zero to 14 according to the person's physical condition. In cases where the person weighs more or less than 70 kg, weight correction is performed.

Finally, the average energy consumption (in kilo calories per minute) is taken in 30 minutes. In order to determine the amount of energy consumed during the shift, the amount of energy consumed for 480 minutes (in case of 8-hour shift) is calculated.

After determining the amount of energy consumed, this parameter is compared with physical work capacity (PWC[2]). If a person's energy consumption is calculated more than PWC, unfavorable conditions are assessed and the person may experience physiological fatigue, otherwise the conditions are assessed favorably. The equation of calculating physical work capacity is as follows:

$$\mathrm{PWC} = \frac{\log 5700 - \log t}{3.1} \times \mathrm{MEE}$$

PWC: Physical Working Capacity ($Kcal.min^{-1}$)

T: Work time (min)

MEE: The most energy a person can consume ($Kcal.min^{-1}$)

---

[1] Systematic Workload Estimation

[2] Physical Work Capacity

$$\text{MEE} = \text{Vo2 max (L/min)} \times 5$$

The maximum amount of oxygen consumed (aerobic capacity) is calculated according to the table below and based on the individual's age:

Total	**Age groups**				**Percentile**
	50 - 59	**40 - 49**	**30 - 39**	**20- 29**	
$L.min^{-1}$	$L.min^{-1}$	$L.min^{-1}$	$L.min^{-1}$	$L.min^{-1}$	
2.07	1.71	1.96	2.33	2.63	5
2.72	1.99	2.41	2.69	2.84	50
3.02	2.56	2.69	2.90	3.17	95

The worksheet of this method is presented in the attachments section. It should be noted that in this phase, the time and duration of rest of each job task (work-rest cycle) is determined.

F) Anthropometric and biomechanical evaluation

A) If there is no proportionality between the anthropometric dimensions of the individual and the workstations and tools used, the physical component score of a unit will be added. It should be noted that the anthropometric evaluation can be qualitative or quantitative. It is suggested to use quantitative anthropometrics in the present model. A summary of the most important definitions in this field is presented below:

Anthropometry:

It is a Greek word composed of two words: Anthropo, meaning human- species, and metery, meaning measurement. Generally, measurements of body dimensions are performed in two situations:

Static status: In a constant state, body measurements are performed when the body has no movement and this measurement is called static anthropometrics.

Dynamic status: In a moving state, measurements of body dimensions will be performed while the body is moving. This measurement is also called dynamic anthropometrics. Generally anthropometrics includes measurements:

1. Different sizes of body length.
2. The weight and volume of the limbs - the space of movement and the angles of movement of each size and finally, the preparation of statistics and information resulting from it in determining the shape and size of the tools and tools that are used in the workplace of these people.

In general, anthropometrics is used in two areas:

1. To adapt and fit the machine with humans in order to easily and increase the efficiency of the user
2. In order to standardize the equipment used for an individual or the whole community in this field, in addition to the body dimensions, type of equipment used, sex and condition of the body or posture, etc. It is used, of course, the most important of which is age, gender and racial differences. In order to standardize how to determine each size, there must also be a specific definition for the type of measurement, which is the main definition in measuring body dimensions.

In this regard, in addition to body dimensions, type of equipment used, sex, strength and pressure tolerance and other human-related factors such as age, sex, race, body structure (exercise, obese, lean), type of job, diet, health status, body posture or posture, time (beginning of day, end of day), voluntary changes (e.g. muscle contraction), clothing and personal equipment are taken into consideration. Of course, the most important of them is age, gender and racial differences.

In some situations, the workspace and equipment are designed exclusively for a particular user, such as ordering clothes to tailors, women's clothing models and racing car seats, which are such things.

The design from anthropometric point of view includes adaptation and coordination and body sizes and dimensions with the dimensions and sizes of the workplace or instrument of the device used. Anthropometry is a part of ergonomics and a branch of anthropometric physics that is about measuring the dimensions of the appearance of different parts of the human body. Because knowing the dimensions and sizes of different organs of the body is essential for the ergonomic design of many living devices, anthropometric knowledge also helps the designer to greatly increase the safety, health and efficiency of his design by measuring and providing different body sizes (such as the length of the hands and feet, shoulder width, scapula, etc.) and determining the field of motion or range of motion to offer.

1. Height is the vertical distance of a part of the body in sitting position or standing to the ground or a horizontal surface. For example, the height of the elbow or knee to the ground in sitting position.
2. Breadth width tells the distances between the two points in the width of the body. Like shoulder or buttock width.
3. Depth of determination of horizontal diameters of the body in the direction perpendicular to the longitudinal axis of the body, e.g. depth of the brace or chest depth.
4. Length or length of the obtained sizes are obtained in the axis along the body, such as the length of the hand.
5. Reaches access limits say the sizes obtained along the hand axis, such as the distance between the forehand to capture objects or the availability of finger pointers to press a key.
6. Circumferences environments, for example, measurement of the environment or waist, where the distance is obtained, is one point to another or the same point on the screen that cuts off the body. This page can be vertical, horizontal or at a certain angle.
7. Curvatures, measuring distances on a curved surface on the body, such as chin curvature.
8. Distance, for example, measure the distance between the fingertips of the two hands when it is completely open.

b) If, according to the assessments performed in occupational tasks in which there is excessive force in the joint and spine area, the amount of occupational strain and torque force applied to the joints is calculated and if the values are in the range greater than the permissible limits, a unit will be added to the physical component score.

Cognitive ergonomics:

This component of ergonomics examines human interaction, work and environment from a cognitive dimension. This review is useful in the design process to ensure safety and prevention of human error. Cognitive ergonomics focuses on designing interactions between humans and work according to the user's cognitive limitations. Cognitive ergonomics studies perceptual processes (such as understanding patterns), central cognitive processing (such as decision making, problem solving, and memory) and sensory, motor processes (such as typing).

In general, the topics discussed in cognitive ergonomics are as:

1. Psychological stages from understanding to action are called cognition.
2. Motor sense skills

3. Perceptual sensory skills of motivation and effective response
4. Attention
5. Learning and Memory
6. Language and Communication
7. Problem solving and decision making
8. Group dynamics and teamwork

Cognition is a general term and describes processes by which humans obtain information from the environment and use that information to regulate their behavior. In other words, cognition refers to all processes in which information obtained through sensory receptors:

1. Transformed
2. described
3. Saves
4. Processed, and it's finally used.

In the present model, the following indicators are used to evaluate this component:

1. Job stress
2. Mental workload
3. Sleep Quality
4. Cognitive failure

A) Job stress assessment

Job Content Questionnaire (JCQ)

In order to assess job stress in the present model, job content questionnaire is used. In this tool, 3 questions were used to assess the dimension of decision-making or control freedom, 5 questions were used to assess the psychological needs dimension of the job, 8 questions were used for assessing the dimension of social support, 5 questions were used for assessing the physical needs dimension of the job and 3 questions were used for assessing the dimension of job insecurity. In order to form a control need model houses, the proposed criteria will be used in the job content questionnaire guide. The validity and reliability of this tool have been confirmed in previous studies (Cronbach's alpha 0.85).

B) Assessment of mental workload

NASA – TLX (Workload Assessment Questionnaire)

NASA-TLX tool is used to evaluate mental workload. NASA-TLX is a multidimensional method that provides an overall score of workload based on the weighted average of six mental scales, physical load, time pressure, amount of effort, performance and efficiency, and a sense of discouragement and frustration. The participant points each of the six defined dimensions from zero to 100 based on their working conditions.

Using analytical hierarchical method (AHP), the importance of each dimension compared to the other dimensions is investigated two by two. In this case, the person chooses from two of the two, the option that is most relevant to that activity. Each time the selection is equal to a weighted score for that case. By multiplying the weight of each dimension of the workload (which is between 0-1) in the scale score of each dimension (between 0-100) the total workload of the individual is calculated numerically between 0 and 100. In fact, the overall obtained score is expressed as weighted workload.

According to this questionnaire, if the total workload score is less than 50, the risk level is low and if it is above 50, the risk level is high. The validity and reliability of this tool have been confirmed in previous studies (Cronbach's alpha: 0.897). The questions and definitions of each scale of this questionnaire are mentioned in Table 1.

Table 1 – Definitions of each subscale of NASA – TLX questionnaire

Subscale	definition
Intellectual workload	How much mental activity is needed to do the job? It is usually evaluated by tl concept of human information processing system.
Physical load	How much physical activity is required to do the job? (In other words, determinii the actual physical needs of the desired work)
Time pressure	As a result of doing the work, how much time pressure is applied to the person? In the sense of duty, the key structure is the time, rate and rate that people need to c their job
The amount of effort	The amount of effort indicates how hard a person has to work (physically ar mentally) to reach the level of performance they want
Function (performance)	It shows the success rate of doing the desired job and achieving the goal
Feelings of discouragement and frustration.	To what extent workers feel uncertainty, frustration and feelings of tension in doir the job in question

C) Evaluation of sleep quality

Pittsburgh Sleep Quality Index (PSQI)

Pittsburgh questionnaire has 7 scales that measure mental sleep quality, delay in falling asleep, duration of useful sleep, sleep adequacy (ratio of sleep duration from time spent in bed), sleep disorders (night wakefulness), sleepiness and daily functioning disorders (problems caused by insomnia during the day). The score of each scale is between 0 and 3 and the score of 3 in each scale indicates the maximum negative value. The overall score of this questionnaire was between 0 and 21 and the overall score of 6 and above indicated inappropriate sleep quality. The validity and reliability of this questionnaire have been confirmed in various studies (Cronbach's Alpha: 0.83).

D) Assessment of cognitive failure

In order to evaluate cognitive failure, the CFQ (cognitive failure questionnaire) is used. This tool consists of 25 questions in 4 subscales of distraction, memory problems, inadvertent errors and lack of remembering names (amnesia). Memory factor includes questions that measure memory failures and amnesia. The distraction factor refers to the perceptual aspects of tasks in which attention is diverted. The cause of inadvertent errors refers to errors in the execution of the work and is associated with physical accidents. The answer to each material is done on a five-degree Likert scale from "never" to "always." The overall score of cognitive failure for each individual is obtained from the sum of the scores of the subscales. Higher scores in the present instrument indicated higher cognitive failure. The validity and reliability of this instrument have been reported in previous studies (Cronbach's alpha: 0.81).

Environmental ergonomics:

It is a branch of ergonomics that investigates the harmful physical factors of the workplace and their desirability and their impact on human resources performance.

To evaluate this component in the present method, the following indicators are used:

1. Noise in the workplace
2. Vibration in the workplace
3. Workplace Lighting
4. Heat stress in the workplace
5. Confined space

A, B) Noise and vibration in the workplace

Exposure to noise and vibration in the workplace can impose many physiological effects on the body. Mental effects, irritability, changes in neural and brain waves, changes in blood pressure and heart rate, hardening of the vascular wall, gastrointestinal dysfunction and increased cholesterol and triglycerides, exacerbation of diabetes and changes in some hormones such as adrenaline and cortisol are noted. In addition, noise pollution along with exposure to vibration can exacerbate musculoskeletal, neuro -psychological, neuro-vascular disorders, diabetes and digestive disorders. Therefore, according to these cases, the exposure of different occupational tasks to noise and vibration as an effective parameter in environmental ergonomics is evaluated.

C) Lighting in the workplace

Optimal lighting can be effective in improving health, comfort, alertness, sleep quality, speed of work, reducing errors and reducing absenteeism and productivity. Inappropriate lighting is one of the potential risk factors for musculoskeletal disorders. Improving brightness can help improve posture and prevent ergonomic disturbances associated with lack of lighting. Therefore, considering the desirability of lighting in different occupational tasks, it is evaluated as an effective parameter in environmental ergonomics.

D) Heat stress in the workplace

Exposure to heat stress in the workplace can always affect people physically and psychologically, including heat exhaustion, heat synchronousness, muscle cramps and heatstroke, ergonomic disorders, decreased physical and mental functioning, reduced productivity and increased absenteeism. Therefore, the amount of heat stress in different occupational tasks is evaluated as an effective parameter in environmental ergonomics.

E) Confined space

In the present model, in order to consider the work in any confined space and create very undesirable postures, the factor of working in the closed space was also considered (applicable in sectors such as maintenance and other occupations that requires changing conditions and working in tight spaces).

Completing the list of parameters used in evaluating the ergonomic risk index

The present study aimed to create an ergonomics management model focusing on three physical, cognitive, and environmental components in the workplace using the Delphi study and fuzzy analytical hierarchy process (FAHP) in a power plant industry in 2021 in Iran.

The location of the study was MAPNA Turbine Engineering and Manufacturing Company (TUGA). This company is the largest producer of turbines and compressors in Iran and has many exports to West Asian countries.

At first, according to the literature review and experts' opinions, the general cycle of ergonomics management and evaluation system consisting of eight main steps was developed. In two of these eight steps, new methods were developed. These steps include the third step (creating a comprehensive ergonomic evaluation method) and the 5th step (developing a cost-benefit evaluation method).

To create an ergonomic evaluation method (3rd step), the following steps were performed:

Identification of the studied items for measuring the parameters

At this stage, to determine the parameters to be measured for each group of occupations, the most important parameters and indicators in each of the ergonomic dimensions; Include physical ergonomics, environmental ergonomics, and cognitive ergonomics using library studies, review of scientific texts published in valid scientific indexes in similar industries in the world (ISI-Web of Science, Scopus, PubMed) as well as obtaining expert opinions were identified. In this step, a total of 116 studies in ergonomic evaluation and management methods in the workplace were extracted. Then, in the second stage and finalization of the selected studies, 43 articles were selected according to the study criteria. The criteria for entering the study included the following:

Conducting studies in similar industries, examining various physical, cognitive, and environmental components, examining the management content of ergonomics, suitable statistical population, being up-to-date (preferably for the last five years), using available and easy-to-use tools, and finally approving the study by an expert's panel to extract the variables under investigation.

Creating an ergonomic index assessment model (ergonomic risk due to job design)

Then, to determine the indicators measured in each job subgroup, jobs in the studied industry were divided into three general groups: office, operational, and service jobs. The following are the definitions of each of the studied components and indicators:

Physical ergonomic

It generally focuses on humans' biomechanical, anatomical, physiological, and anthropometric properties. This branch of ergonomics examines the effect of physical factors on the performance of individuals.

The following parameters were used to evaluate this component:

- Body Posture (BP)
- Manual material handling (MMH)
- Prevalence, severity, and disabilities caused by musculoskeletal disorders (WRMSDs)
- Muscle fatigue (MF)
- Energy consumption (EC) or work physiology (determining the amount of energy consumed in each job based on past empirical studies)
- Biomechanics and anthropometry

Cognitive ergonomic

This ergonomic component studies human, work, and environment interactions cognitively. Cognitive ergonomics focuses on designing the interaction between humans and work settings according to the mental limitations of the user. Cognitive ergonomics studies perceptual processes (such as recognizing patterns, and central cognitive processing (such as decision-making, problem-solving, memory, and sensory-motor processes)).

The following parameters were used to evaluate this component:

- Mental workload (MW)
- Occupational stress (OS)
- Sleep quality (SQ)
- Burnout
- Cognitive failure (CF)

Environmental ergonomics

It is a branch of ergonomics that studies the work environment's harmful physical agents, the degree of desirability, and their impact on human performance.

The following parameters were used to evaluate this component:

- Sound in the workplace
- Vibration in the workplace
- Workplace lighting
- Heat stresses in the workplace
- Work in confined space

Delphi study

The Delphi method and Analytic Hierarchy Process (AHP) were used to complete the list of measured parameters according to the industry and the weighting of criteria and sub-criteria. The

Delphi method is a structured communication methodology or technique initially developed for prediction based on the opinion of experts. The basis of the Delphi method is that the idea of experts in any scientific field about anticipating the future is the most correct. Participants in the Delphi study included 5 to 20 individuals.

After selecting the parameters affecting the ergonomic index in this study, a Delphi questionnaire was designed. In the present study, to adequately integrate the majority of the country's specialists, the opinions of 30 experts with master's and doctoral degrees were collected in the fields of occupational health, ergonomics, occupational medicine, and physiotherapy and working in 25 universities and 15 large power plants and manufacturing industries in three stages of Delphi study. In the first phase of the Delphi study, experts were asked to comment on the model's overall structure, and if they had other components or parameters in mind in this stage, the model's overall design was approved. In the second stage, experts were asked to prioritize components and parameters according to their importance. In the third stage, the second stage results were provided to the panel, and they were asked to comment on any changes in their indicators and priorities. It was found that the results of the third stage did not differ significantly from the second stage, and therefore the Delphi study was completed in three phases.

At the end of this phase, all studied parameters, tools to measure the values of indicators, and their scoring range are determined according to the expert's panel and the importance of each component (criteria) and indicator. The fuzzy analytical hierarchy process (FAHP) was used to measure (sub-criteria) in each job subgroup and determine each parameter's weight.

The content validity ratio (CVR) and content validity index (CVI) were employed to determine the content validity of the model. The acceptable limit of the CVR was considered 0.33 based on the Lawshe table and proportional to the number of participants in the Delphi study (30 experts). The acceptable limit value of the CVI was considered to be 0.79. Cronbach's alpha method was utilized to evaluate the overall reliability of the model. To assess the internal consistency of the model, 130 workers from three occupational groups, administrative or office (N= 44), operational (N= 43), and service (N= 43), were investigated during the pilot stage. An alpha coefficient of 0.7 or higher was considered the minimum score required to approve the model's reliability. SPSS software version 25 was used to calculate descriptive statistics (mean, standard deviation, frequency, etc.) and Cronbach's alpha.

Analytic Hierarchy Process (AHP)

The **a**nalytic hierarchy process is a multi-criteria decision-making technique for weighing the criteria and selecting the optimal option. Thomas Saaty presented this method in 1983. The purpose of this method is to prioritize several criteria or options. Once the goal has been selected, criteria for decision-making must be determined. These criteria are paired based on purpose, and their weight is determined. Finally, the options are paired based on each criterion, and the final priority of the options is determined. This technique makes it possible to formulate the problem hierarchically. The primary purpose of the analytic hierarchy process method is to select the best option based on various criteria by creating a pairwise comparison matrix.

In the analytic hierarchy process, the elements of each level are compared in pairs at a higher level than their respective element, and their weights are calculated, called relative weights. Next, the final weight of each option is specified, which is called the absolute weight. Then the weight of the criteria is determined concerning the goal, and combining them determines the final weight of the options. All comparisons in the analytical hierarchy process are made in pairs. In these comparisons, decision-makers will use verbal judgments. Then, to increase the reliability of the results of the questionnaires' analysis, the system's consistent rate was controlled, and the acceptable amount of the decision was calculated. In the expert panel questionnaire, which is based on pairwise comparisons of all elements, the probability that a variable is not considered is zero.

The comparison and weighing of factors are recorded in a K × K matrix (K = number of rows and columns of the pairwise comparisons matrix). The pairwise comparison is conducted based on the valuation of the row factor relevant to the column element. For valuation, a distance scale varying from 1 to 9 is usually employed based on language terms: a higher value indicates the superiority of a row element over a column element so that a value of 9 means the most valuable element, and a value of 1 means the least valuable element (Table 2).

Table 2. Language expressions and corresponding fuzzy weights

Language expression	Numerical weight	Fuzzy weight (triangular fuzzy number)
Definitely more important	9	(9,9,8)
Intermediate	8	(9,8,7)
More important	7	(8,7,6)
Intermediate	6	(7,6,5)
Relatively important	5	(6,5,4)
Intermediate	4	(5,4,3)
A bit more important	3	(4,3,2)
Intermediate	2	(3,2,1)
Equally important	1	(1,1,1)

Fuzzy Logic

Fuzzy logic is a form of the multi-valued region in which the variables' accurate values may be any actual number between zero and one. This logic is employed to apply the concept of partial correctness so that its values can be between entirely accurate and completely false. This approach is a strong tool to deal with the vagueness and uncertainty of human judgment and evaluation in decision-making.

In the hierarchical analysis strategy, verbal expressions are utilized to compare the criteria in pairs and express the importance of the criteria concerning each other. This technique's disadvantage is that the verbal terms are inaccurate, indefinite, and ambiguous, making it challenging to analyze and summarize the results, given that a fuzzy region is a convenient tool for measuring vague concepts related to people's mental judgments. As a result, it is a powerful tool appropriate for overcoming the mentioned concerns and makes it possible to acquire more accurate information in verbal expressions. Different studies have used combining the AHP method with fuzzy logic to rank and weight the criteria and sub-criteria. Various methods for performing FAHP have been suggested. This study was based on the method suggested by Chang because it is more comfortable to implement than other approaches and supplies accurate results. Therefore, in this study, the ergonomic risk index (ERI) and related components have been calculated based on Equations 1-4 and Figure 9-11.

Therefore, because all elements have been evaluated in this assessment and the designer cannot orient the design specifically, questionnaires based on pairwise comparisons have validity. The reliability values of the expert panel questionnaire were considered the same as the adjustment rate. This study regarded a value of 0.1 or less as the acceptable compatibility limit for pairwise comparisons.

Finally, employing the studied method and based on the parameters in each component, the ergonomic conditions of each job task will be evaluated based on the division of jobs. Finally, it will gain an ergonomic risk index, which is the basis for the decision and taking control measures.

Development of ergonomic cost-benefit evaluation method (Step 5)

In the present study, an ergonomic cost-benefit evaluation is performed after ergonomic evaluation and before performing control measures. For this purpose, the following steps are performed:

1) Equivalence and calculation of all musculoskeletal disorders and ergonomics costs, including costs of treatment, rehabilitation, absence from work, morbidity, reduced productivity, etc.

2) Equivalence and calculation of all costs related to the control and intervention measures

3) Compare the mentioned costs

For this purpose, according to previous studies conducted in ergonomic investments and also summarizing the parameters affecting the cost-benefit assessment using the brainstorming of the expert's panel to calculate the parameter and the approach of realizing and adjusting costs based on workers' age, the average age of workers with musculoskeletal disorders in each department, duration of employment to get WRMSDs, the prevalence of ergonomic diseases in each of the operational, office and service occupational subgroups and ergonomic risk index of each individual (The result of the third step). This step will ultimately determine which planned control measures can be implemented. All experimental coefficients used in this step were extracted using the existing documents in the studied industry, such as personnel reports and medical records. All formulas and computational coefficients used in this section were studied using SPSS and Excel software.

TEMA findings

A total of 30 experts were involved in the present study. The expert panel's age and work experience were 39.66 ± 7.13 and 7.88 ± 4.13 years, respectively. 70.6% of the experts were Ph.D., and 29.4% had an MS degree. The three-stage Delphi study showed that the number of deleted parameters was one item (burnout from the cognitive ergonomics component), and the number of remaining parameters in the model was 16.

The mean CVI was 0.92 (the obtained value was higher than 0.79, and the content validity of the model was verified). The mean CVR was also determined to be 0.80.

The overall average was higher than 0.33 according to the number of panel members and the Lawshe method, and was approved. To evaluate model reliability, 130 employees from three occupational groups, administrative (N=44), operational (N=43), and service (N=43), were investigated during the pilot phase. The mean and standard deviation of age and work experience of the subjects were 43.57±7.36 and 10.41 ± 4.82 years, respectively.

10% of the studied workers were female, and 90% were male. 23% had a diploma, 26% had a master's degree, 45% had a bachelor's degree, and 6% had a master's degree.

Cronbach's alpha values for each of the physical, environmental, and cognitive components and the entire model were 0.91, 0.87, 0.85, and 0.89, respectively, and model reliability was proved. Finally, the findings mentioned above showed that in the initial model, after conducting a three-stage Delphi study and implementing the pilot phase on 130 people, the validity and reliability values of the model were acceptable.

The final models for the three office, operational, and services occupational groups are presented in Figures 10-12.

Finally, the ergonomics management cycle was investigated in 8 steps. The study cycle is presented in Figure 9 and describes the steps used to manage and evaluate ergonomics.

The eight implementation steps of the TEMA model were defined as follows:

Step 1) Performing tabular task analysis (TTA)

Step 2) Ergonomic hazard identification (EHI)

Step 3) Ergonomic risk index estimation for each of tasks (ergonomic risk due to job design)

Step 4) Determining control measures

Step 5) Evaluating cost-benefit parameter

Step 6) Implementing control measures

Step 7) Continuous monitoring

Step 8) Evaluating the effectiveness of control measures.

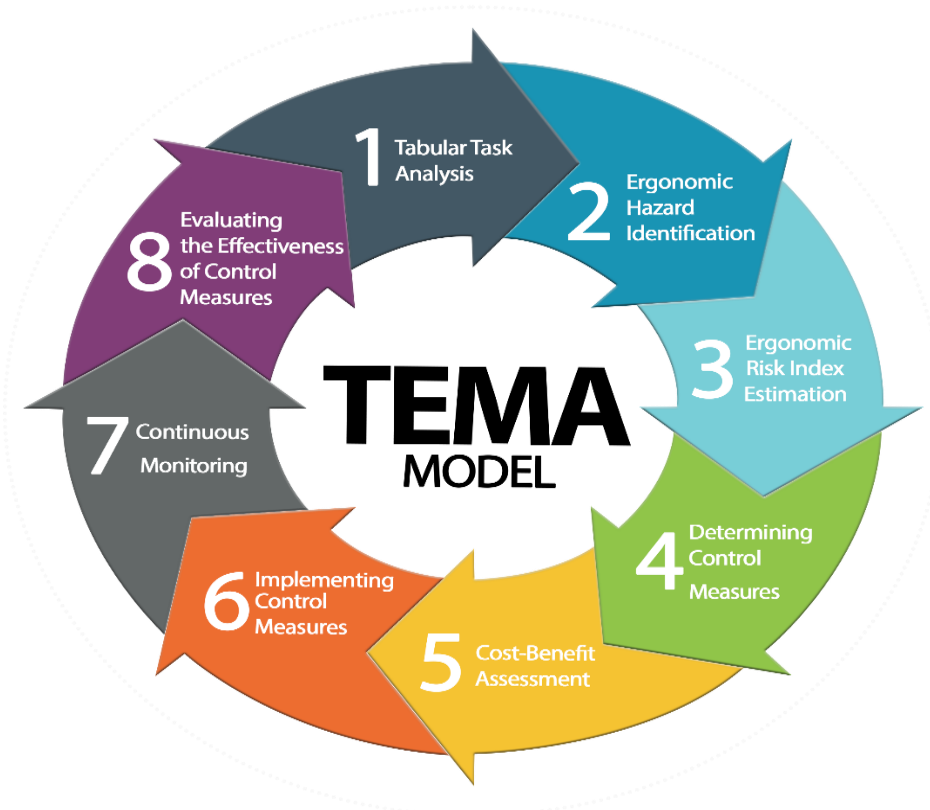


Figure 9. TUGA ergonomics management and analysis model (TEMA)

Step 1) Tabular task analysis (TTA)

To analyze the tasks and sub-task of existing jobs, a tabular analysis of tasks is employed. This section divides existing jobs into tasks, sub-tasks, and basic motion elements (like flexion, extension, elevation, etc.). All ergonomic risk factors in each job task will be identified. The TTA worksheet is provided in Table 3. After the training course, the staff completes this step with a participatory ergonomic approach. This step is the central part of identifying ergonomic hazards.

Table 3. Tabular Task Analysis (TTA) Worksheet

Unit:			Sector:			Date:
Job	**Task**	**Sub-Task (Work Element)**	**Ergonomic Risk F.***	**Sub-Task Time**	**Total Time (in shift w.)**	**Basic Motion Element****

* Posture, force, repetitive movement, vibration, time, MMH, pulling, pushing, etc.
** Flexion, extension, hyper extension, abduction, adduction, supination, pronation, elevation, depression.

Analyzer: ………………………….…………..

Step 2) Ergonomic hazard identification (EHI)

The following tools and methods can be employed to identify ergonomic risk factors and hazards (such as improper posture, force application, repetitive movements, vibration, duration, manual material handling, carrying, pulling, pushing, etc.):

- Using standard ergonomic checklists
- Using TTA results
- Using ergonomic checkpoints
- workstations field visits
- Workers' statements about musculoskeletal disorders
- Investigate work absences, employee complaints, etc.
- Check for inappropriate postures and repetitive movements
- Study reports on first aid and medical services
- Check the type of tools and equipment employed and workers' ergonomics situation

An example of the factors used in the identification of ergonomic hazards is presented below:

I. Anthropometric, Biomechanical, and Physiological Factors

1. Are the differences in human body size accounted for by the design?
2. Have the right anthropometric tables been used for specific populations?
3. Are the body joints close to neutral positions?
4. Is the manual work performed close to the body?
5. Are any forward-bending or twisted trunk postures involved?
6. Are sudden movements and force exertion present?
7. Is there a variation in worker postures and movements?
8. Is the duration of any continuous muscular effort limited?
9. Are the breaks of sufficient length and spread over the duration of the task?
10. Is the energy consumption for each manual task limited?

II. Factors Related to Posture (Sitting and Standing)

1. Is sitting/standing alternated with standing/sitting and walking?
2. Is the work height dependent on the task?
3. Is the height of the worktable adjustable?
4. Are the height of the seat and backrest of the chair adjustable?
5. Is the number of chair adjustment possibilities limited?
6. Have good seating instructions been provided?
7. Is a footrest used where the work height is fixed?
8. Has work above the shoulder or with hands behind the body been avoided?
9. Are excessive reaches avoided?
10. Is there enough room for the legs and feet?
11. Is there a sloping work surface for reading tasks?
12. Have combined sit–stand workplaces been introduced?
13. Are handles of tools bent to allow for working with the straight wrists?

III. Factors Related to Manual Materials Handling (Lifting, Carrying, Pushing and Pulling Loads)

1. Have tasks involving manual displacement of loads been limited?
2. Have optimum lifting conditions been achieved?
3. Is anybody required to lift more than 23 kg?
4. Have lifting tasks been assessed using the NIOSH (Waters et al., 1993) method?
5. Are handgrips fitted to the loads to be lifted?
6. Is more than one person involved in lifting or carrying tasks?
7. Are there mechanical aids for lifting or carrying available and used?
8. Is the weight of the load carried limited according to recognized guidelines?
9. Is the load held as close to the body as possible?
10. Are pulling and pushing forces limited?
11. Are trolleys fitted with appropriate handles and handgrips?

IV. Factors Related to the Design of Tasks and Jobs

1. Does the job consist of more than one task?
2. Has a decision been made about allocating tasks between people and machines?
3. Do workers performing the tasks contribute to problem solving?
4. Are difficult and easy tasks performed interchangeably?
5. Can workers decide independently on how the tasks are carried out?
6. Are there sufficient possibilities for communication between workers?
7. Is sufficient information provided to control the tasks assigned?
8. Can the group take part in management decisions?
9. Are shift workers given enough opportunities to recover?

V. Factors Related to Information and Control Tasks

Information

1. Has an appropriate method of displaying information been selected?
2. Is the information presentation as simple as possible?
3. Has the potential confusion between characters been avoided?
4. Has the correct character/letter size been chosen?
5. Have texts with capital letters only been avoided?
6. Have familiar typefaces been chosen?
7. Is the text/background contrast good?
8. Are the diagrams easy to understand?
9. Have the pictograms been used properly?
10. Are sound signals reserved for warning purposes?

Control

1. Is the sense of touch used for feedback from controls?
2. Are differences between controls distinguishable by touch?
3. Is the location of controls consistent, and is sufficient spacing provided?
4. Have the requirements for control–display compatibility been considered?
5. Is the type of cursor control suitable for the intended task?
6. Is the direction of control movements consistent with human expectations?
7. Are the control objectives clear from the position of the controls?
8. Are controls within easy reach of female workers?
9. Are labels or symbols identifying controls used properly?
10. Is the use of color in controls design limited?

Human–computer interaction

1. Is the human–computer dialogue suitable for the intended task?
2. Is the dialogue self-descriptive and easy to control by the user?
3. Does the dialogue conform to the expectations on the part of the user?
4. Is the dialogue error-tolerant and suitable for user learning?
5. Has command language been restricted to experienced users?
6. Have detailed menus been used for users with little knowledge and experience?
7. Is the type of help menu fitted to the level of the user's ability?
8. Has the QWERTY layout been selected for the keyboard?
9. Has a logical layout been chosen for the numerical keypad?
10. Is the number of function keys limited?
11. Have the limitations of speech in human–computer dialogue been considered?
12. Are touch screens used to facilitate operation by inexperienced users?

VI. Environmental Factors

Noise and vibration

1. Is the noise level at work below 80 dBA?
2. Is there an adequate separation between workers and source of noise?
3. Is the ceiling used for noise absorption?
4. Are acoustic screens used?
5. Are hearing conservation measures fitted to the user?
6. Is personal monitoring to noise/vibration used?
7. Are the sources of uncomfortable and damaging body vibration recognized?
8. Is the vibration problem being solved at the source?
9. Are machines regularly maintained?
10. Is the transmission of vibration prevented?

Illumination

1. Is the light intensity for normal activities in the range 200 to 800 lux?
2. Are large brightness differences in the visual field avoided?
3. Are the brightness differences between task area, close surroundings, and wider surroundings limited?
4. Is the information easily legible?
5. Is ambient lighting combined with localized lighting?
6. Are light sources properly screened?
7. Can light reflections, shadows, or flicker from the fluorescent tubes be prevented?

Climate

1. Are workers able to control the climate themselves?
2. Is the air temperature suited to the physical demands of the task?
3. Is the air prevented from becoming either too dry to too humid?
4. Are drafts prevented?
5. Are the materials/surfaces that have to be touched neither too cold nor too hot?
6. Are the physical demands of the task adjusted to the external climate?
7. Are undesirable hot and cold radiation prevented?
8. Is the time spent in hot or cold environments limited?
9. Is special clothing used when spending long periods in hot or cold environments?

Step 3) Ergonomic risk index estimation (ergonomic risk due to job design)

To determine the indicators to be measured in each job subgroup, the jobs in TUGA Company were divided into three general groups: office, operational, and service jobs. In the following, each studied parameter is presented in the main components of ergonomics and the calculation method.

Ergonomic index leveling

Finally, the risk matrix was designed based on the values of the three studied ergonomic components. Then it was divided into three levels of acceptable (low), tolerable and recoverable (medium), and unacceptable (high) risk in accordance with the principle of ALARP (As low as reasonably practicable) and the opinion of the expert's panel. For this purpose, the maximum tolerable ergonomic index (average risk) in each physical, environmental and cognitive component was determined. The maximum final tolerable ergonomic score was defined according to the values of the three components, and the risk matrix was formed. The following equations are proposed to calculate the ergonomic risk index due to job design:

$$ERI = [PE \times W] + [CE \times W] + [EE \times W] \quad (1)$$

$$\text{Physical Ergonomics} = \sum P_i W_{pi} \quad (2)$$

$$\text{Cognitive Ergonomics} = \sum C_i W_{Ci} \quad (3)$$

$$\text{Environmental Ergonomics} = \sum E_i W_{Ei} \quad (4)$$

Where,

ERI: Ergonomic risk index

PE: Physical ergonomic

CE: Cognitive ergonomic

EE: Environmental ergonomic

Pi: Numerical index of physical ergonomic sub-parameters

Wpi: Normalized weight of physical ergonomic sub-parameters

Ci: Numerical index of cognitive ergonomic sub-parameters

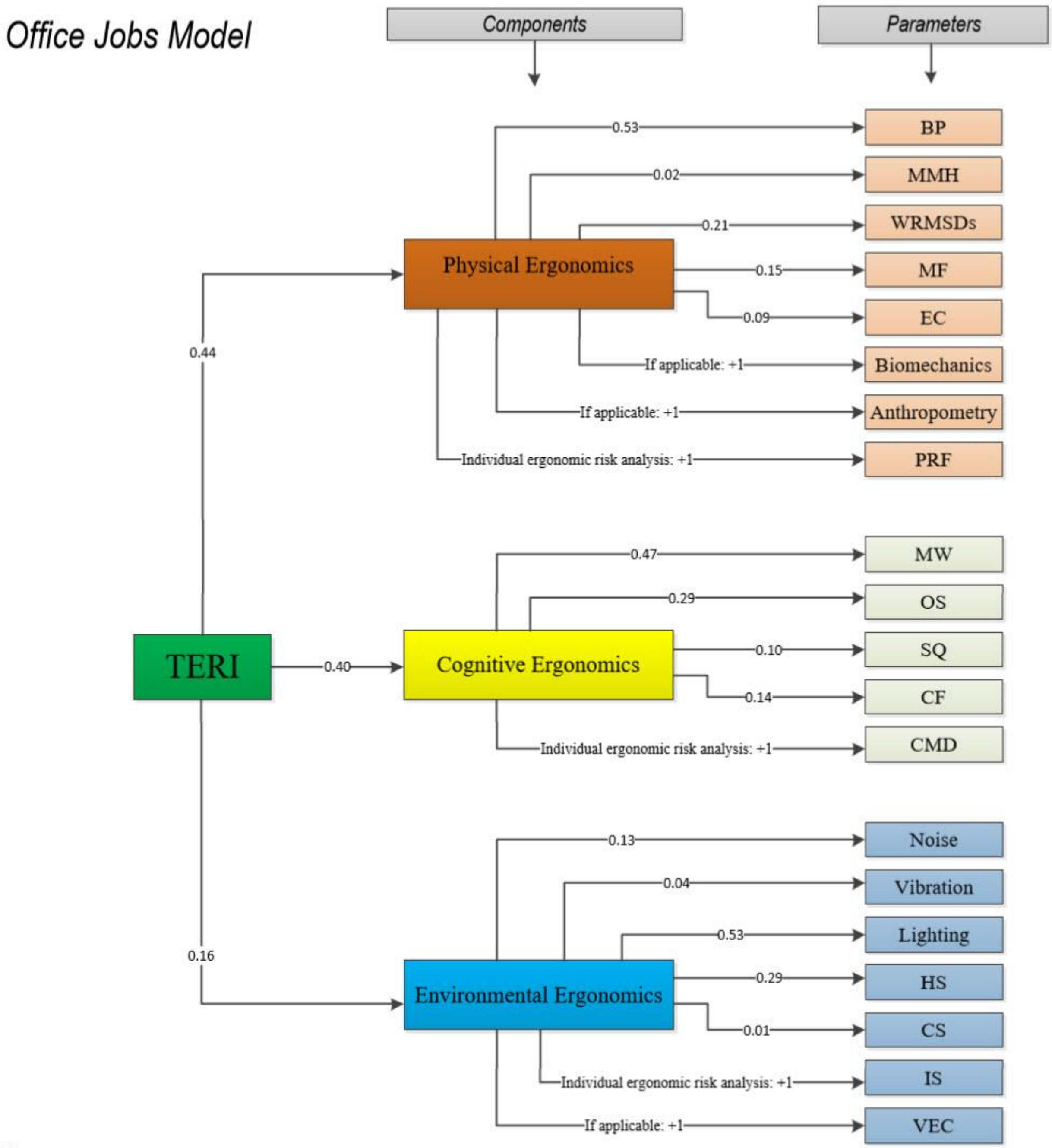
W_{ci}: Normalized weight of cognitive ergonomic sub-parameters

E_i: Numerical index of environmental ergonomic sub-parameters

W_{Ei}: Normalized weight of environmental ergonomic sub-parameters

W: Normalized weight of ergonomic risk index parameters

The input values for determining the scoring values of the physical, cognitive, and environmental components and the guide for determining the risk level of the ergonomic index are given in Tables 4-7. The proposed methods for calculating parameters and components are among the most widely used and easy-to-use tools. Based on our review, these tools are the most reliable and common tools employed by Iranian ergonomists. Previous studies have also determined that these tools are among the most widely used ergonomic assessment tools in the world.



Note:
TERI: TUGA Ergonomic Risk Index ; **BP**: Body Posture; **MMH**: Manual Material Handling; **WRMSDs**: Work-Related Musculoskeletal Disorders; **MF**: Muscle Fatigue ;**EC**: Energy Consumption ;**PRF**: Personal Risk Factor; **MW**: Mental Workload ;**OS**: Occupational Stress ;**SQ**: Sleep Quality; **CF**: Cognitive Failure; **CMD**: Chronic Mental Disorders; **HS**: Heat Stress; **CS** :Confined Space; **IS**: Individual Sensitivity; **VEC**: Variable Environmental Conditions.

Figure 10. Ergonomic evaluation model of office jobs

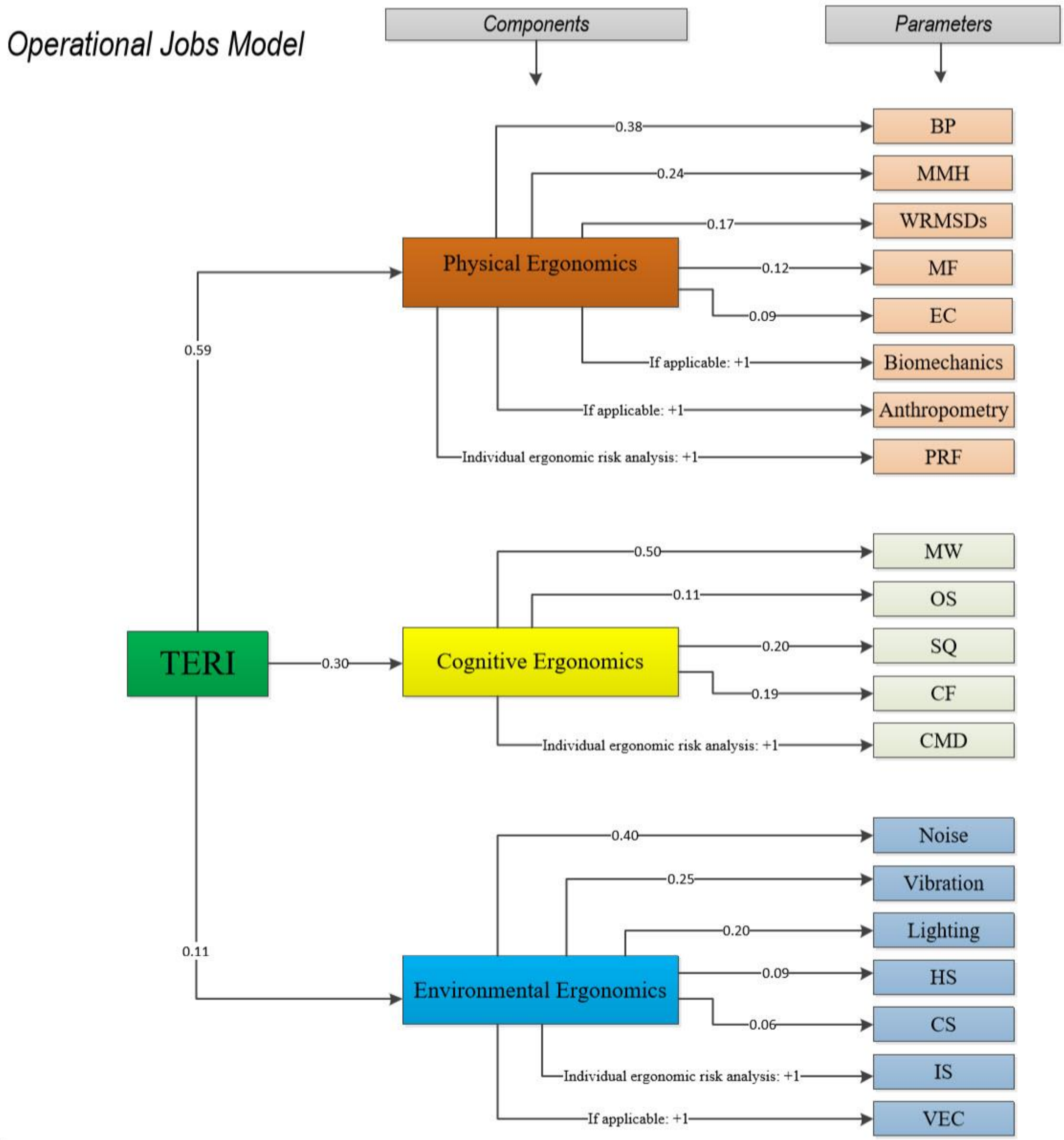


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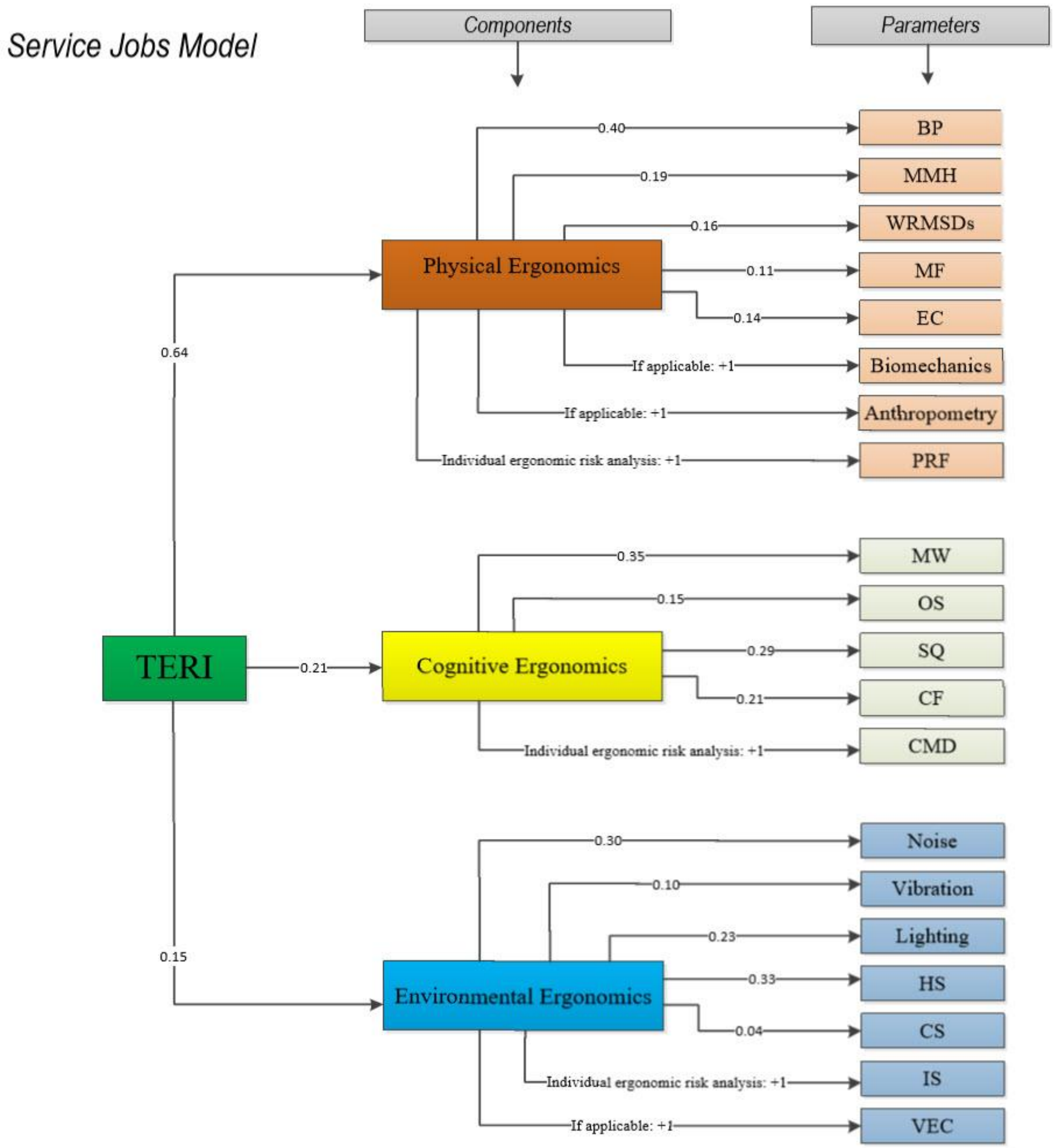
Figure 11. Ergonomic evaluation model of operational jobs



Note:
TERI: TUGA Ergonomic Risk Index ; **BP**: Body Posture; **MMH**: Manual Material Handling; **WRMSDs**: Work-Related Musculoskeletal Disorders; **MF**: Muscle Fatigue ;**EC**: Energy Consumption ;**PRF**: Personal Risk Factor; **MW**: Mental Workload ;**OS**: Occupational Stress ;**SQ**: Sleep Quality; **CF**: Cognitive Failure; **CMD**: Chronic Mental Disorders; **HS**: Heat Stress; **CS** :Confined Space; **IS**: Individual Sensitivity; **VEC**: Variable Environmental Conditions.

Figure 12. Ergonomic evaluation model of services jobs

Table 4: Scoring guide for the determining parameters and measuring tools in physical ergonomics

Parameters	Tools	Range of Score / Risk Level	Final Score: Real Score	Final Score: Model Score
Posture	Rapid Entire Body Assessment (REBA)	1-15	1-3	0
			4-7	1
			8-10	1.5
			11-15	2
	Rapid Upper Limb Assessment (RULA)	1-7	1-2	0
			3-4	1
			5-6	1.5
			7	2
	Rapid Office Strain Assessment (ROSA)	1-10	1-4	0
			5-7	1
			8-9	1.5
			10	2
Manual Material Handling	WISHA Lifting Calculator	Variable	<PEL	0
			=PEL	1
			>PEL	2
	Snook Tables	Variable	<PEL	0
			=PEL	1
			>PEL	2
WRMSDs*	Cornell Musculoskeletal Discomfort Questionnaires (CMDQ)	0-90	0-20	0
			21-40	1
			41-60	1.5
			61-90	2
Muscle Fatigue	Muscle Fatigue Assessment (MFA)	Low, Moderate, High and Very High Risk Level	Low	0
			Moderate	1
			High	1.5
			Very High	2
Energy Consumption	*Systematic* Workload *Estimation* (SWE)	Lower / Higher than Physical Work Capacity (PWC)	<PWC	0
			= PWC	1
			> PWC	2
Anthropometry**	Qualitative Assessment	Suitable / Not Suitable	Not Suitable	+1
Biomechanics***	Job Strain Index(SI-JSI)	Low, Moderate and High Risk Level	>7.1	+1
Personal Risk Factor****	Questionnaire – Medical Examination	-	Existence of Risk Factors	+1
Final Score	Without Normalized Weight	Job Assessment: 0-12	Low	0-0.99
		Personal Assessment: 0-13	Moderate	1-1.99
	With Normalized Weight	Job Assessment: 0-4	High	2-2.99
		Personal Assessment: 0-5	Very High	3-5

* Work Related Musculoskeletal Disorder (Prevalence, Severity and Disability)
** If Applicable
*** In the case of Individual index calculation

Table 5: Scoring guide for the determining parameters and measuring tools in cognitive ergonomics component

Parameters	Tools	Range of Score / Risk Level	Final Score	
			Real Score	**Model Score**
Mental Workload	NASA Task Load Index (NASA – TLX)	0-100	<45 45-55 >55	0 1 2
Occupational Stress	Job Content Questionnaire (JCQ)	Variable	Low High	0 2
Sleep Quality	Pittsburgh Sleep Quality Index *(PSQI)*	0-21	0-6 >7	0 2
Cognitive Failure	Cognitive Failure Questionnaire (CFQ)	0-125	0-25 26-50 51-75 76-125	0 1 1.5 2
Chronic Mental Disorders*	Questionnaire – Medical Examination	-	Presence of Risk Factors	+1
Final Score	Without Normalized Weight	Job Assessment: 0-8 Personal Assessment: 0-9	Low Moderate	0-0.49 0.50-0.99
	With Normalized Weight	Job Assessment: 0-2 Personal Assessment: 0-3	High Very High	1-1.99 2-3

* In the case of Individual index calculation

Table 6: Scoring guide for the determining parameters and measuring tools in environmental ergonomics component

Parameters	Tools	Range of Score / Risk Level	Final Score Real Score	Final Score Model Score
Noise	Environmental/ Personal Assessment	0-140 dB for environmental assessment, >100 % Dose for personal assessment	0-65 dB 66-82 dB 82-85 dB >85 dB and Dose > 100 %	0 1 1.5 2
Vibration	Whole Body Vibration (WBV) / Hand-Arm Vibration (HAV)	0.87 $m.s^{-2}$ for WBV and 2 $m.s^{-2}$ for HAV (OEL)	Lower than allowed level Higher than allowed level	0 2
Lighting	Environmental/ Local Assessment	270 Lux for Lighting and 100 nit for Illuminance (OEL)	Lighting>270 Lux Illuminance < 100 nit Lighting<270 Lux Illuminance > 100 nit	0 2
Heat Stress	Direct Measure	Existence of heat stress	In allowable Range Out of allowable Range	0 2
Confined Space	Observation Method	Existence / Not Existence	Not Existence Existence	0 2
Variable Environmental Condition*	Observation Method	Existence / Not Existence	Existence	+1
Vulnerability to Environmental Risk **	Questionnaire – Medical Examination	Existence / Not Existence	Existence	+1
Final Score	Without Normalized Weight With Normalized Weight	Job Assessment: 0-11 Personal Assessment: 0-12 Job Assessment: 0-3 Personal Assessment: 0-4	Low Moderate High Very High	0-0.99 1-1.99 2-2.99 3-4

* If Applicable
** In the case of Individual index calculation

Table 7: Guide for the determining risk levels of the ergonomic risk index or ergonomic risk due to job design

Range of Score	Risk Level	Control Measures
0 - 1.99	Acceptable (Low)	No need any control measures
2 - 3.99	Tolerable and Recoverable (Moderate)	Need for control measures in near future
> 4	Not Acceptable (High)*	Urgent demand for control measures

* If one of the three components in the model scores the maximum score or is at a very high-risk level, the overall ergonomic index will be within the not-acceptable (high) risk level range.

Step 4) Determining control measures

At this stage, all proposed control measures are proposed to reduce ergonomic risk levels regardless of their cost-effectiveness. Also, at this stage, participatory ergonomics is employed for the second time. At this stage, an ergonomics committee is formed, including the employee, their direct manager, and an ergonomics expert. The employee offers all their suggestions to improve their work's ergonomics according to the training received. The reasonable recommendations of the employees for control measures are combined with the suggestions of the ergonomic expert and enter the phase of evaluating the cost-benefit parameter.

Step 5) Evaluating cost-benefit parameter

After ergonomic evaluation and determination of intervention and control measures, and before performing control measures, a cost-benefit assessment is completed. For this purpose, the following steps are conducted:

1) Equivalence and calculation of all costs related to musculoskeletal and ergonomics disorders, including the costs of treatment, rehabilitation, absence from work, etc., of the relevant employee, calculated according to the ergonomic risk level. It should be noted that cases such as absences due to disorders and reduced productivity during recovery can be among the costs of disorders.

Note 1: The total costs considered in this step include only direct and calculable costs. According to the iceberg model (Iceberg theory direct vs. indirect costs), the ratio of direct to indirect costs is 1:4.

Note 2: The sum of the costs of the disorders is calculated based on the level of risk and is equalized by considering a coefficient for the probability of payment (P). The final cost is obtained from the following equation:

$$EC = C \times ERI \times P \qquad (5)$$

EC: Costs of Equivalent Disorders (USD)

P: Probability of payment in the organization

ERI: Ergonomic risk index

C: Total Occupational Outcome Costs (USD)

The P coefficient in TUGA in each occupational group (administrative, operational and support jobs) is calculated from the following formula:

$$P = A \times (D / B) \qquad (6)$$

P: Probability of payment in the organization for each job group

B: Total number of employees in the occupational group / Number of employees with ergonomics disorders

D: The average year of onset of disorders after employment in TUGA

A: The average age of employees with disorders in the occupational group / average age of the occupational group

2) Calculation of all costs related to the implementation of control and intervention measures

3) Compare the mentioned costs and determine the cost-benefit parameter based on the following equation:

$$CB = EC / CC \quad (7)$$

CB: Cost-benefit parameter

EC: Total equivalent costs of disorders (USD)

CC: The sum of the costs of the specified control measures

Finally, a decision will be made on the implementation of the planned control measures as follows:

- If the value of the Cost-benefit (CB) parameter is greater than or equal to one, it is economically viable to perform the specified control measures and is considered desirable.

- If the value of the Cost-benefit (CB) parameter is less than one, performing the specified control measures is not economically viable, is not considered desirable, and needs reconsidering.

Step 6) Implementing control measures

The hierarchy of control measures will be as follows (Figure 13):

A) Technical - engineering: such as redesigning workstations to suit working conditions and anthropometric dimensions of individuals, using ergonomic tools, etc., using existing standards and ergonomic checkpoints.

B) Managerial-executive: such as training to observe ergonomic principles in the workplace, training of corrective exercises, job rotation, work time management, and work cycle regulation - rest, exceptional attention to participatory ergonomics, check the amount of physical activity and workers' diet.

C) Tools and equipment: Although this group of measures does not have the same efficiency as engineering and management interventions, a wide range of items designed based on ergonomic principles are available to use in work environments and can improve the performance and comfort of staff.

D) Participatory Ergonomics: One of the most important and influential approaches to reducing the burden of musculoskeletal disorders in the workplace is Participatory Ergonomics (PE), which has entered the science of ergonomics with industrial management measures used in quality cycles, industrial democracy, and the participatory controls used in Asian, European, and American countries. There are a variety of techniques and models for participatory ergonomics, some of which involve the ergonomist or instructor as a facilitator. Commitment and understanding of management, providing the required resources for participatory ergonomics programs by the ergonomist, and the degree of employee acceptance of ergonomic concepts, have an influential role in ergonomic success and the resulting improvements in the workplace. This section will be done to increase the level of personnel awareness, create an ergonomic culture and turn it into personnel habits, and study the principle of knowledge in the resilience engineering approach and integrate it with ergonomic principles.

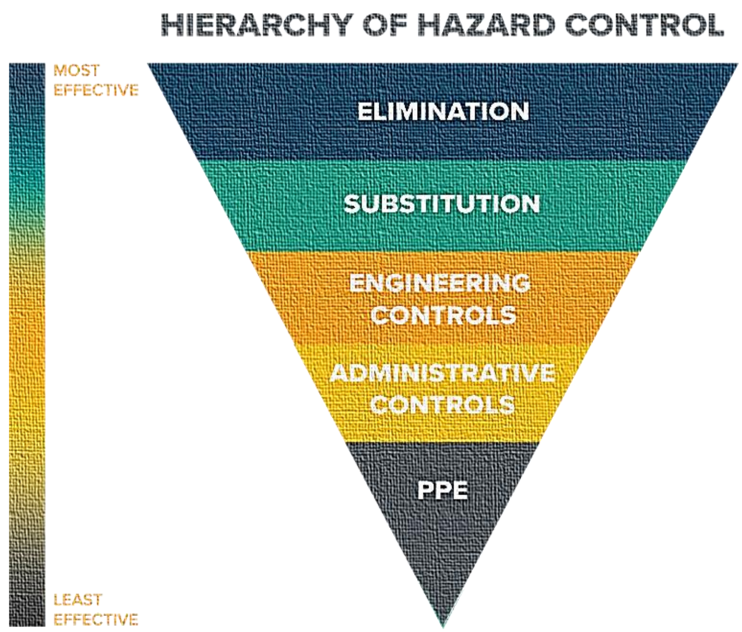


Figure 13. Prioritization of ergonomic interventions during the present study

A common element in all participatory ergonomics programs is "improving staff knowledge and skills in ergonomics and involving them in proposing and implementing ergonomic interventions." One of the disadvantages of the participatory ergonomic approach is that it is sometimes an inefficient way to provide control solutions due to time-consuming and the need for employee participation. Sometimes, the proposed solutions are not optimal. However, participatory ergonomics for having human-centered work environments is a practical approach to improving the organizational climate and a helpful way to avoid musculoskeletal disorders caused by manual tasks that are always validated. Among the applied and implemented cases in the ergonomics management model in TUGA Company, the following can be mentioned:

- Request to declare ergonomic risk factors by workers
- Involve workers in the project and seek the opinions of staff in the field of intervention measures
- Assign worksheets related to ergonomic hazard reporting in the workplace and suggest control strategies to eliminate hazards.
- The effect of staff participation in ergonomics management programs on the parameter of organizational productivity of individuals.
- Encourage personnel to Improving lifestyle parameters (like reduce body mass index and so on).

All of the above can be a positive step towards creating an ergonomic culture and other issues related to safety and health in organizations and industries.

Occupational ergonomic qualification criteria

It should be noted that in order to more accurately implement the preventive and proactive approach in the present model, after the ergonomic evaluation phase and data acquisition and in the ergonomic intervention phase, the general characteristics of new employees, as well as different workstations in the form of a guideline, will be provided. The main purpose of this section is to increase the degree of matching between the abilities and characteristics of workers with job requirements. The output of this step can be a comprehensive guide to assessing the ergonomic professional qualifications of new personnel and all employees.

Prioritization of job duties in order to perform control measures will be based on the following:

- The ergonomic risk index score
- Number of relevant complaints
- Type of injuries and complications
- Identified risk factors
- Staff comments
- Available financial and technical resources

Step 7) Continuous monitoring

According to the concepts of the Deming cycle and focusing on the ideas of continuous improvement and Kaizen in the field of ergonomics, the identified job tasks in the biennial period are evaluated ergonomically, the ergonomic index is calculated according to the developed model, and control measures are performed based on the obtained results.

It should be noted that the above period is contractual. In case of any change in the conditions and workstations and personnel working in different occupations, the current ergonomic status will be re-examined.

Step 8) Evaluating the effectiveness of control measures

After ergonomic interventions, ergonomic evaluation (step 3) will be performed again, and the measures' effectiveness will be investigated. If the desired risk levels are not studied, additional measures will be taken to reduce the risk levels.

Furthermore, in this stage, the principles of implemented interventions are evaluated using periodic inspection, using the camera and continuous monitoring of personnel, encouraging people to self-control and participatory ergonomics, and completing the relevant checklists to adapt the existing cases to the expected rates.

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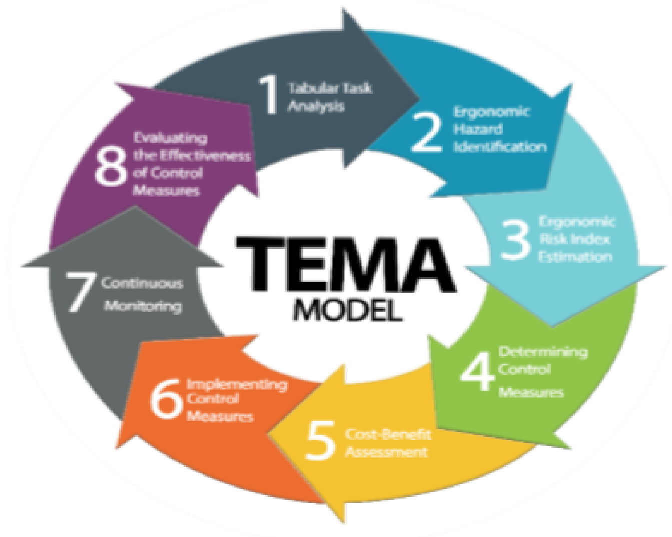
Ergonomics Management in the Workplace (Introducing to TUGA Ergonomics Management & Analysis model: TEMA)



The most important features of the TEMA:

- Comprehensive and unique in ergonomic management based on the PDCA cycle and resilience engineering
- Using the latest scientific and experimental findings
- Using the opinions of academic, medical and industrial elites
- Being job-oriented
- Based on participatory ergonomics
- Evaluation of innovative ergonomic risk index (ERI) based on fuzzy analytical hierarchy process (FAHP) focusing on three physical, environmental and cognitive components.
- Economic evaluation of ergonomic interventions and estimation of cost-benefit parameter