Ergonomics and Work style Risk Factors Assessment in Construction Industry Using Machine Learning

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Abstract: Construction works are physically very dangerous. There are many situations that contribute to injuries and fatalities. Because the work has to be performed at different sites ranging from buildings and highways to demolition sites and excavations work. Individuals on the job have to operate variety of tools, control machines, move heavy objects, repair equipment, as well as monitor processes. This job requires an individual who has great manual dexterity as well as the ability to think quickly and intelligently. Since construction jobs are so demanding physically on a person's body, a variety of injuries can occur. This is more aggravated by its labour intensive nature and also the low level of mechanization. Therefore it is important for employers to provide a safe environment for their construction workers. This study aims at examining the current level of adoption of ergonomic practices in construction industry in Kerala. Also the study includes understanding the ergonomic risk factors and the benefits of ergonomic solutions. A total of forty-five criteria were identified based on a thorough literature review. Relative index analysis was used to determine the relative ranking of the criteria as perceived by respondents. Hypothesis testing was conducted to determine the relation among the factors. Ergonomic stress assessment model was made using the machine learning approach. The focus is on understanding and interpolating the emotional state of a person in workplace. Adequate ergonomic design and solutions can prevent and reduce the risk of musculoskeletal disorders (MSDs). Every organization should assess the ergonomic hazards on its job sites, based on the scope of work, injury history, and the work practices. Some of the most common ergonomics methods for stress management focus on the physical stress assessment using musculoskeletal posture analysis. Despite the mental stress of the employees also has to be considered. Employee's moods, emotions and overall dispositions have an impact on job performance, decision-making, creativity, turnover, teamwork, negotiations and leadership.
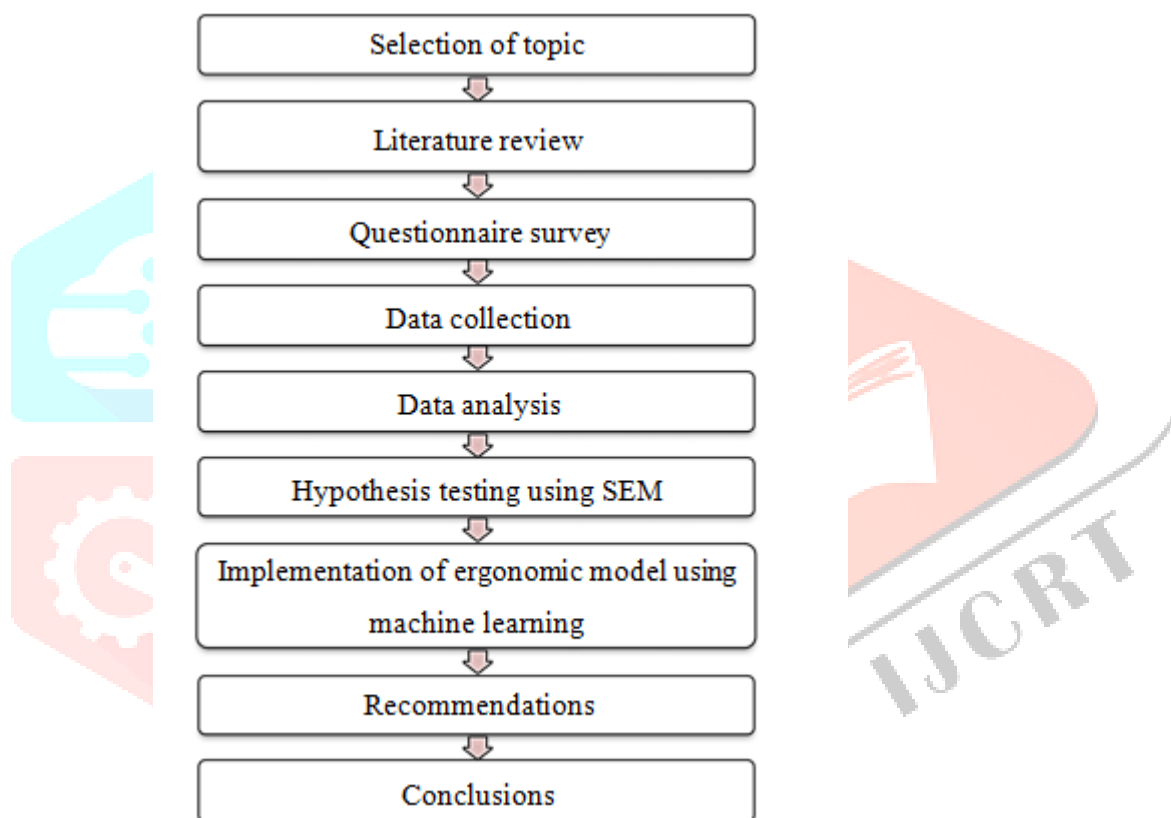
Key words: Ergonomics, Ergonomic risk factors, Ergonomic stress assessment, Mechanization, Musculoskeletal disorders

I.INTRODUCTION

Protecting the safety and health of construction workers is challenging due to diversity and dynamic features of construction industry. As far as a human being was considered safety, comfort, physical and mental wellbeing are important. Traditionally, people have been adaptive to workplaces and working environment but there is remarkably less attention given on how to fit workers to such workplaces. The increasing numbers of injuries caused by repetitive motion, awkward postures and use of excessive force has become an important factor in workplace safety. With increasing development of the construction process, still building workers seem to be constantly exposed to unfavorable ergonomic challenges by its wide range of activities.

Construction is ergonomically hazardous, whose works typically require the adopting of awkward postures, frequent bending and twisting of body, lifting of heavy materials, manual handling of heavy loads, working below the knee level, working above shoulders height, staying in one position for a long period, pushing and pulling of loads. This can result in injuries or related problems involving the tendons, muscles, or nerves. The highest worker injury and fatality rates make construction industry an extreme risk sector in regard to Work-Related Musculoskeletal Disorders (WMSDs). Because of work types involved, WMSDs are one of the leading causes of occupational injuries in the construction industry. Here comes the importance of ergonomics. Ergonomics is a science discipline which is concerned with understanding the relationship between humans and social-technical system element. In larger scope, ergonomics examines human behavioral, physiological and psychological capabilities and limitation. The goal of ergonomics is to achieve a balance between work tasks and the worker that will optimize productivity and, at the sametime, preserve the safety and health of the employee. Ergonomics focus on providing a best fit between the worker and their job.

II. METHODOLOGY

III. LITERATURE REVIEW

Ahankoob, Alireza, and Aref Charehzehi. (2013) the paper gives a basic overview of ergonomic risk factors and tries to develop control measures for preventing accidents which are possible to happen in feature and also provides a comprehensive monitoring to minimize and avoid such risk factors. Construction industry is one of the risky industries with high level of injuries. A musculoskeletal disorder that is one of ergonomic injuries is the most common problem in the construction industry. This type of injury can really affect the health of the people that are exposed to the hazards for a long period of time. The purpose of this paper is to discuss the way to control ergonomic risk factors in construction operations and also monitor and assess the process of program implementation to prevent or cut out ergonomic risk factors in the construction industry.

Damaj, Omar, et al. The study highlights numerous difficulties faced on construction sites, analyzes the barriers that are preventing ergonomics from being implementedin Lebanon, and discusses potential solutions. This study was used as basis for possible future implementation plans and further studies focusing on ergonomics in

Lebanon and the Middle East. Data from field surveys and site visits from several construction sites were analyzed to assess the use of ergonomics.

David, Geoffrey C (2015) this review provides an overview of the range of methods that have been developed for the assessment of exposure to risk factors for WMSDs. The methods have been categorized under three main headings. It consist of self-reports from workers can be used to collect data on workplace exposure to both physical and psychosocial factors. By using methods that include worker diaries, interviews and questionnaires and observational methods for systematically recording workplace exposure enable an observer to assess and record data on a number of factors.

IV. EXPERIMENTAL STUDY

Data Processing and Data Analysis

Data collected through questionnaire survey has to be evaluated for intercepting the results. Large amounts of data have to be analyzed to identify common patterns and trends to convert them into meaningful information. A series of actions or steps are performed on data to verify, organize, transform, integrate, and extract data in an appropriate output form for subsequent use.

Frequency Analysis Using IBM SPSS Statistics

The software IBM SPSS Statistics is used to evaluate the responses events frequency, and intensity. SPSS Statistics is a software package used for interactive or batched, statistical analysis. It was used to analyze, better understanding of the data, and solve complex business and research problems through a user friendly interface. Tests are available to determine the reliability. Reliability refers to the extent to which a scale produces consistent results, if the measurements are repeated a number of times. In reliability analysis, internal consistency is used to measure the reliability of a summated scale where several items are summed to form a total score. This measure of reliability in reliability analysis focuses on the internal consistency of the set of items forming the scale. Understanding large and complex data sets quickly with advanced statistical procedures helps to ensure high accuracy and quality decision making. The software was designed to solve business and research problems using hypothesis testing, geospatial analysis and predictive analytics. SPSS's Visualization Designer program is used to convert data to a wide variety of visuals like density chartsand tables.

Relative Importance Index Analysis

Besides identifying the factors influencing ergonomics, this study used the Relative Importance Index (RII) based analysis to reveal the most significant ergonomic risk factor in the Kerala's construction industry as well as the best ergonomic solution. RII is a statistical approach and highly used tool for ranking factors. Here independent variables are correlated to each other. It is an alternative to multiple regression technique. The various factors are ranked using RII methods to reach at a conclusion regarding most affecting and least affecting ergonomic risk factors and ergonomic solution to contain the risk in construction sector. The factors are ranked by following formula.

$$RII = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A \; x \; N}$$

RII = Relative Importance Index

n_5 = no of respondents for strongly agree

n_4 = no of respondents for agree

n_3 = no of respondents for no comment / neutral

n_2 = no of respondents for disagree

n_1 = no of respondents for strongly disagree

A = highest weight

N = total number of respondents

Structural Equation Modeling Using IBM SPSS Amos

Structural equation modeling is a multivariate statistical analysis technique that is used to analyze structural relationships. This technique is the combination of factor analysis and multiple regression analysis. It was used to analyze the structural relationship between measured variables and latent constructs. This method is preferred by the researcher because it estimates the multiple and interrelated dependence in a single analysis. In this analysis, two types of variables are used endogenous variables and exogenous variables. Endogenous variables are equivalent to dependent variables and exogenous variables are equal to the independent variable. There are two types of models. They are measurement model and Structural model. The measurement model represents the theory that specifies how measured variables come together to represent the theory. Structural model represents the theory that shows how constructs are related to other constructs. Structural equation modeling is also called casual modeling because it tests the proposed hypothesis. Hypothesis testing was used to test the validity or trueness of a conclusion or argument against a data set.

Implementation of Ergonomic Model Using ML

Proper ergonomic design and solutions can prevent and reduce the risk of musculoskeletal disorders (MSDs). While these disorders are generally short-term, they can develop into long-term, disabling conditions that will severely impact an employee's ability to perform their work and enjoy their life. Every organization should assess the ergonomic hazards on its job sites, based on the scope of work, injury history, and the best business practices. This hazard assessment should be the foundation of the ergonomics program. Some of the most common ergonomics methods for stress management focus on the physical stress assessment using musculoskeletal posture analysis. Despite the mental stress of the employees also has to be considered, because it impacts both the employee and employer. An easy way to judge the mental stress of workers is through facial expressions.

Incorporating machine learning and the concept of image processing, a suggestive ergonomic model for stress assessment was proposed. Programmers choose a machine learning model to use, supply the data, and the computer model train itself to find patterns or make predictions. Machine learning is an important component of the growing field of data science. Through the use of statisticalmethods, algorithms are trained to make classifications or predictions.

V. RESULTS AND DISCUSSIONS

Based on the study conducted, the following general and specific results are obtained. This section examined the basic characteristics of respondents as well as participants understanding and awareness of ergonomics in construction industry. It was focused on identifying the ergonomic risk factors, benefits of application of ergonomic practices in construction industry and providing a suggestive ergonomic stress assessment model.

Ergonomic risk factors

Human/Labor related Factors	Tasks-related factors	Equipment/tools-related factors
Bending	Methods of work	Tools/equipment
Squatting	Work load	Equipment heavy to handle
Standing	Climate/environment	Difficulty in grasping
Stretching	Repetitive work	Handles to grasp
Suddenly changing position	Lack of rest	Accident while using a hand tool
Twisting	Awkward posture	PPE create difficulty/obstruction
Kneeling	Static Posture	
Stooping	Strenuous Task	
	Physically tired	
	Overall discomfort-level	

Ergonomic solutions

Solving Ergonomic Problems	Integrating Ergonomics into the Workplace
Starting an ergonomic early intervention process	Creating an internal group to take a leadership role within the operation
Designing an effective job rotation	Developing internal policies and procedures
Identifying the process change	Internal audits
Design and redesign principles	Risk identification
Office ergonomics	Purchasing procedures
Well operated construction activities	Medical management
Safe working environment	Host of other necessary areas
	A system for documenting progress and measuring success

Benefits of ergonomics

Benefits of Ergonomic Training
Lower the incidence of musculoskeletal injuries
Keep skilled and valuable employees at work
Reduce workforce absenteeism
Achieve greater production consistency
Achieve higher levels of quality management
Improve operating profits by lowering injurycosts and improving production levels

Human/Labor related factors, RII and rank

Human/Labor related Factors	Code	RII	Rank
Bending	H1	0.5579832	6
Squatting	H2	0.5344538	8
Standing	H3	0.5739496	4
Stretching	H4	0.5840336	2
Suddenly changing position	H5	0.5932773	1
Twisting	H6	0.5428571	7
Kneeling	H7	0.5789916	3
Stooping	H8	0.5655462	5
Average RII and overall rank		0.6472989	I

Tasks-related factors, RII and rank

Tasks-related factors	Code	RII	Rank
Methods of work	T1	0.5739496	10
Work load	T2	0.6	7
Climate/environment	T3	0.6016807	6
Repetitive work	T4	0.6067227	4
Lack of rest	T5	0.592437	9
Awkward posture	T6	0.610084	3
Static Posture	T7	0.602521	5
Strenuous Task	T8	0.6134454	1
Physically tired	T9	0.5991597	8
Overall discomfort-level	T10	0.6117647	2
Average RII and overall rank		0.6011765	III

Equipment/tools-related factors, RII and rank

Equipment/tools-related factors	Code	RII	Rank
Tools/equipment	EQ1	0.5865546	6
Equipment heavy to handle	EQ2	0.6344538	1
Difficulty in grasping	EQ3	0.6285714	3
Handles to grasp	EQ4	0.6016807	5
Accident while using a hand tool	EQ5	0.6310924	2
PPE create difficulty/obstruction	EQ6	0.6109244	4
Average RII and overall rank		0.6155462	II

Solving ergonomic problems, RII and rank

Solving Ergonomic Problems	Code	RII	Rank
Starting an ergonomic early intervention process	SERP1	0.6327731	1
Designing an effective job Rotation	SERP2	0.5428571	7
Identifying the process change	SERP3	0.5907563	2
Design and redesign principles	SERP4	0.5579832	6
Office ergonomics	SERP5	0.5815126	3
Well operated construction Activities	SERP6	0.5764706	4
Safe working environment	SERP7	0.5739496	5
Average RII and overall rank		0.5794718	II

Integrating ergonomics into the workplace, RII and rank

Integrating Ergonomics into the Workplace	Code	RII	Rank
Creating an internal group to take a leadership role within the operation	IEW1	0.6369748	1
Developing internal policies and procedures	IEW2	0.594958	5
Internal audits	IEW3	0.602521	4
Risk identification	IEW4	0.6218487	2
purchasing procedures	IEW5	0.5831933	7
Medical management	IEW6	0.5857143	6
Host of other necessary areas	IEW7	0.6159664	3
A system for documenting progress and measuring success	IEW8	0.5815126	8
Average RII and overall rank		0.60283613	I

Benefits of ergonomic training, RII and rank

| Benefits of Ergonomic Training	Code	RII	Rank
Lower the incidence of musculoskeletal injuries	BET1	0.6352941	1
Keep skilled and valuable employees at work	BET2	0.5697479	6
Reduce workforce absenteeism	BET3	0.6151261	2
Achieve greater production consistency	BET4	0.5907563	3
Achieve higher levels of quality management	BET5	0.5806723	4
Improve operating profits by lowering injury costs and improving production levels	BET6	0.5773109	5

Least and most contributing factors

Factors	Ergonomic Risk Factors	Ergonomic Solutions	Ergonomic Benefits
Most contributing	Suddenly changing position	Creating an internal group to take a leadership role within the operation	Lower the incidence of musculoskeletal injuries
Least contributing	Methods of work	Designing an effective job rotation	Keep skilled and valuable employees at work

Structural Equation Modeling Using IBM SPSS Amos

IBM SPSS Amos was the software adopted for structural equation modeling. The software was used for conducting SEM, path analysis, CFA etc. We can determine the correlation, variance, regression between variables. Correlation measures the degree of relationship between two variables. Regression measures how one variable affects other and covariance indicates the direction of linear relationship. SEM is a combination of factor analysis and multiple regression analysis used toanalyze the structural relation between variables. A SEM consist oftwo models, measurement model and structure model. Here H1, H2, H3...H8, T1, T2, T3…T10 andso on are called indicators. They are the item in

the questionnaire. That is observed endogenous variables. e1, e2, e3…are corresponding errors. HRF, TRF, ERF, SEP, BET, IEWP are called latent variables, unobserved exogenous variables.
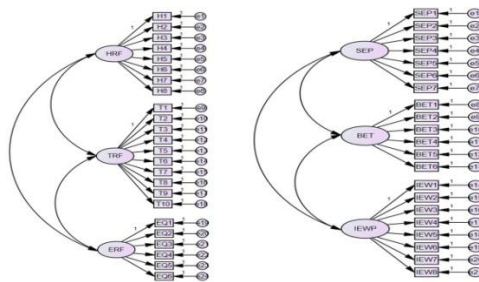
Model check

DOF	Condition	Check
DOF = 0	Just identified	Model 1, DOF = 186 → Over identifiedModel 2, DOF = 249 → Over identified
DOF > 0	Over identified	
DOF < 0	Un identified	

Construct validity

Factors		Convergent validity	Discriminant validity	Correlation
Ergonomic Risk Factors	HRF	0.857	0.926	0.15
	TRF	1.033	1.016	0.05
	ERF	1.983	1.408	0.1
Ergonomic Solutions	SEP	0.731	0.731	0.15
	BET	0.895	0.895	0.05
	IEWP	0.940	0.940	0.1

Model fitness

Models	CMIN/DF	RMSEA	Model Fitness
Ergonomic Risk Factors	2.237	0.072	Acceptable fit
Ergonomic Solutions	2.378	0.076	Acceptable fit

Model check

DOF	Condition	Check
DOF = 0	Just identified	Model 1, DOF = 250 → Over identifiedModel 2, DOF = 249 → Over identified
DOF > 0	Over identified	
DOF < 0	Un identified	

Model Fitness

Models	CMIN/DF	RMSEA	Model Fitness
Ergonomic Risk Factors	2.344	0.075	Acceptable fit
Ergonomic Solutions	2.492	0.079	Acceptable fit

Hypothesis Testing

Hypothesis	P	Support
H1	0.075	Rejected
H2	0.284	Rejected
H3	***	Accepted
H4	***	Accepted

VI. SUGGESTIONS

1. Workstation design: Should be designed to accommodate the population that will assign to the workstation. The design should fit all size of worker. The design should consider the type of the task to be performed.

2. Work method design: Static, awkward and extreme postures, repetitive movements, and excessive forces should minimize. The strength and endurance requirements of the jobs should bewithin the workers abilities.

3. Tool and handle design: Ergonomically designed tools and handles can reduce the risk of cumulative trauma disorders (CTDs). Various sizes of tools should be provided for a proper fit rather than one size fits all. Special purpose tools should be used where needed for certain job.

4. Providing rest breaks to recover from work induced fatigue.

5. Increase the number of employees assigned to a task to distribute the overall load over a larger number of individuals.

6. Establishing an effective mechanism to ensure that facilities, equipment and tools are wellmaintained.
The ergonomic approach to work place design must be recognized at the earlier stage and be considered as one of the most essential factors in designing a workplace. Suitable design will be the most effective and it is the first choice for controlling sources of workplace stress.

VII. CONCLUSIONS

1. The study has revealed that the adoption of ergonomic practices in Kerala's construction industry is in moderate level but the respondent's awareness is high.

2. Respondent's have the collective opinion that ergonomically designed workplace was required, because creating ergonomically comfort workplace decreases the risk towards WMSDs.

3. Job matching was the ergonomic program element currently adopting in the construction sector. Each job demands persons with corresponding skills.

4. Among ergonomic risk factors most contributing factor was suddenly changing position. In most times the workers want to change their position suddenly, they need to stand, bend, stretch and twist according to their work.

5. Among ergonomic solutions most contributing factor was creating an internal group to take a leadership role within the operation. Creating a narrow span of control rather than a wide span of control help the leader to take care of each worker, by considering their difficulties, stress and emotions.

6. There is a significant relationship between solving ergonomic problems and achieving ergonomic benefits. Similarly between integrating ergonomics in workplace and achieving ergonomic benefits. Benefits of ergonomic training were that it lowers the incidence of musculoskeletal injuries. When proper trainings are provided to the employees, it creates more awareness among the employees regarding the work associated risk.

7. In this project, I propose a system that can identify and monitor emotions of the person in an environment and provide a real-time feedback mechanism to enhance the mental health aids for a healthy person. Evaluating the emotion of a person can progressively help in enhancing their mental health.

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