

Indian Journal of Engineering & Materials Sciences Vol. 27, August 2020, pp. 860-865



Development of a NIOSH based software tool for musculoskeletal disorders

Sanjay Mohan^{a*}, Ankush Anand^a, Mir Irfan Ul Haq^a, Ankush Raina^a, Rajiv Kumar^a & Mohd Kamal^b

^aSchool of Mechanical Engineering, Shri Mata Vaishno Devi University, Katra, 182 320, Jammu & Kashmir, India ^bAdvanced Composite Research Unit, Faculty of Engineering,

University Malaysia Sabah, Malaysia 88818

Received: 26 May 2020

Musculoskeletal disorders amongst workers performing manual lifting tasks have become a major challenge now a days. Such problems hamper productivity of any concern to a greater extent. Industrial experts and researchers have been devising ways and means to reduce such disorders and the National Institute of Occupational Safety and Health (NIOSH) agency lifting equation is one amongst such tools. NIOSH lifting equation has significantly enhanced the safety of the workers involved in manual lifting tasks. With this equation, a prior indication of musculoskeletal disorders can be obtained from the workers anthropometric details. However, till date there is no such tool available with which we can have recommendations to eliminate/reduce such disorders. In this paper an expert system on the basis of NIOSH equation has been developed to deal with the musculoskeletal problems amongst the workers involved in manual lifting tasks. The expert system is basically a computer programme developed to facilitate the use of NIOSH lifting equation. On the basis of lifting parameters, this equation computes recommended weight limit (RWL) and lifting index (LI). These outputs have been further analyzed by the programe to check existing working conditions against occupational hazards, and suggest recommendations for the safe working conditions.

Keywords: NIOSH, Recommended weight limit, Lifting index, Manual lifitng, Programme

1 Introduction

Automation still has not dominated the manual lifting in most of the Industries. The statistics show that manual material handling tasks are prevalent in one third of all industrial jobs¹. While handling the material, the workers suffer from musculoskeletal disorders. Low back pain (LBP) has caused major musculoskeletal disorders along with financial losses to both employers and the employees. LBP frequently occurs in the places where lifting of materials is carried out manually². The spinal loading has been found to enhance due to vibrations at the work place, repetitive work, heavy load lifting, static postures, frequent bending and twisting, etc.³. As per National Safety Council's Accident Facts⁴, back injuries account for 32% of all worker compensation cases, thus declaring it to be the most common disabling occupational hazard in the United States. Another study reported disability due to LBP amongst 5.2 million individuals. Amongst these, 2.6 million people were temporarily disabled and rest were chronically disabled. The estimated expenses attributed to low-back pain vary from \$16 billion to

*Corresponding author (E-mail: sanjaysmvdu@gmail.com)

more than \$50 billion⁵. LBP at the workplace resulted in huge medical expenses and it has been reported that 25% of all musculoskeletal injuries in United States were compensated. These injuries happened during manual tasks, and pain in the lower back was predominant. The Liberty Mutual Insurance Company in 1989 assessed lower back pain claims to be 33% of the total claims nearing to an expenditure⁶ of \$ 991,000,000. These claims are much more than indirect costs such as absenteeism, loss of productivity, holding workers, etc. Latest statistics projects low back pain to be one of the highest industrial injury taking place due to manual tasks and has an ongoing trend across the world. In United States, lower back pain has affected almost seventy million people, and seven million are adding to the lot on annual basis. In addition to this, tasks such as pulling, lowering, carrying, etc. has resulted in half a million injuries out of which 50-60% of the injuries are due to lower back pain⁷. The research of industrial injuries carried out in Korea at the workplace of Mando Machinery Corporation Ltd. reflects that during the first half of 1997, 46% industrial injury cases out of 1527 workers have been reported. Among the total injuries, 45.65% were attributed to low back

pain, due to repeated manual material handling (MMH) tasks⁸.

The National Institute of Occupational Safety and health (NIOSH) is the agency created by "The Occupational Safety and Health Act of 1970" in the U.S. Department of Health and Human Services. This agency ensures safe and healthy working environment for working persons, both male and female by providing them with updated information, and training related to occupational safety and health.

The problem of work-related back injuries was recognized by NIOSH and to deal with such problems, they had devised a tool for evaluating risks associated with manual lifting. This tool is basically an equation commonly known as NIOSH lifting equation⁹⁻¹¹. NIOSH lifting equation (NLE) is used to assess two-handed lifting tasks with an objective of investigating growing problem of lower back injuries. This equation includes a lifting equation which is basically a multiplicative model with six inputs and two inputs. NLE gives Recommended Weight limit (RWL) and Lifting Index (LI) for various inputs like weight, height and distance of the object to be lifted, type of hand-object couplings, frequency of lifting, asymmetrical angles, etc.¹². The objective of the equation is to inhibit or decrease the occurrence of lower back injuries among workers. The equation has also been reviewed and validated number of times¹³⁻¹⁵. Amongst the outputs of NLE, LI provides a comparative assessment of the physical stress related to manual lifting task *i.e.*, if the LI is higher than 1.0, it indicated high risk for lower back pain. The use of rapid upper limb assessment (RULA) and rapid entire body assessment (REBA) techniques has also aided researchers to locate awkward body postures and safeguard workers^{16,17}. Researchers have also been developing new ways and means to deal with the similar industrial and societal problems. Various smart systems have been developed in order to safeguard and facilitate human labor¹⁸⁻²⁰.

In the present work, a computer programme has been developed with which the workers exposed to risk of musculoskeletal disorders can be assessed, and consequently safety of the workers is ensured by implementing the recommendations given by the computer programme. The programme accepts inputs as six variables which are basically the body measurements taken while lifting are being carried out by the worker. The processing is carried out by the programme and thus safe recommendations are made.

2 Methodology

The methodology adopted for the current paper comprises of the following steps:

- (a) The NIOSH equation has been studied thoroughly along with its applications. The literature review is carried out, and the recommendations as suggested in the respective literature have been considered^{21,22}.
- (b) Existing NIOSH based calculators were evaluated and their limitations were considered. Based upon these, the need for the Expert System (programme) was ascertained. The calculations of the RWL and LI is a laborious job when carried out manually as it consumes lot of time. It becomes more complicated when one has to change the task variables according to the place where worker is performing his/her lifting job, followed by recalculation of the RWL and LI. Thus considering these limitations, the following programme has been developed.
- (c) Few NIOSH calculators are also available on internet but they too have limitations as follows
- Lack of range of task variables i.e they are left with very few options for the task variables.
- Suggest only the output value without any interpretations / recommendations.
- (d) There are benefits offered by the proposed system. The developed programme:
- Not only gives the output but also suggests safe and unsafe values of various lifting parameters.
- Clearly specifies the changes to be carried out in respective task variables if found unsafe in order to safe guards workers from any disorder.
- Is absolutely user friendly as one has just to enter the task variables taken at the origin and destination of the lift and rest of the calculation is done by the programme.
- The programme suggests recommendations which if implemented will definitely result in safe working environment.
- The architecture and the flowchart of the programme has been developed and discussed in the following section.
- The programming language used for the development of the programme is C++ as it is readily available and easily understood.

3 Design

The design phase comprises of the following: (a) Architecture of the programme (b) Algorithm of the programme

(c) Flowchart of the programme

3.1 Architecture of the programme

The basic architecture of the computer programme is as shown in Fig. 1. The task variables such as horizontal reach, vertical distance, frequency *etc*. measured at the time of the lifting, both at origin as well as the destination serve as the input which is to be given by the user. The programme then calculates the multipliers for each of the task variable using various tables and equations as mentioned in the NIOSH work practice guide²⁰. These multipliers then form the basis for the NIOSH lifting equation which finally calculates and displays RWL and the LI.

The programme further checks if the LI calculated at the origin as well as the destination is safe or not. If it is safe then the same is displayed and if the results are unsafe, the programme further compares each of the task variables given by the user with the safe values as given in the NIOSH work practice guide²⁰⁻²³. The task variables which are unsafe are displayed along with the changes as recommended by the programme. The user on implementing these recommendations will get safe lifting index and thus safe working environment.



Fig. 1 — Architecture of the programme.

The programme has been developed in C++ language and is DOS based. It is very easy to use, as at every step it asks user to input the data and results are displayed in such a way so that they are easily interpreted by the user.

3.2 Algorithm of the programme

This section describes the algorithm of the developed computer programme and below mentioned are the steps of the algorithm:

- 1. Start of the programme.
- Declare and initialize various variables and constants involved such as LC, H1, H2, V1, V2, A1, A2, etc.
- 3. Declare various functions to be included in the programme
- 4. Get the input from the user for the various task variables for both, at origin and at destination of the lift.
- 5. Corresponding to the task variables, call the respective functions to get the value for various multipliers and display the same.
- 6. Calculate the values of RWL and LI and display the same.
- 7. Check for the LI, at origin and at destination of the lift and display the information if it is safe.
- 8. If check performed in step vii is not safe, then again check for the LI at origin only.
- 9. If LI at origin is safe then skip the Step x.
- 10. If LI at origin is unsafe then check for the safe limits for each task variable and display the respective recommendations.
- 11. If LI at destination is safe then skip the Step xii.
- 12. If LI at destination is unsafe then check for the safe limits for each task variable and display the respective recommendations.
- 13. If LI at origin and destination is safe then skip Step xiv.
- 14. If LI at origin or destination is unsafe, then check for frequency of lifting, coupling and duration of lifting and make the respective recommendations.
- 15. Enquire from the user whether he/she wants to continue.
- 16. If user enters 'Yes', then repeat all the steps starting from Step 4.
- 17. If user enters 'NO', then exit the programme.

3.3 Flow chart for the programme

Based upon the algorithm as discussed above, flowchart has been prepared as shown in Fig. 2. The computer programme has been developed based



Fig. 2 — Flow chart of the programme.

upon the flowchart, and the output of the programme is discussed in the succeeding section.

4 Results and Discussion

4.1 Testing

The programme developed was finally tested for its authentication. Few sample readings were taken on the site and thereafter manual calculations for the same were done for RWL and LI. The same readings were fed to the programme and the RWL and LI were obtained. These results were then compared with the manually calculated results using tables as mentioned in NIOSH work practice guide²³. It was ensured that the results obtained from the programme are accurate and reliable as the programme incorporates the maximum flexibility.

4.2 Program results

The data taken from a worker carrying out manual lifting is as mentioned in Table 1. The input data was fed to the programme and the results were then

	Table 1 — Input parameters for NIOSH equation	n.
S.No	Variable description	Value
1	Horizontal Task Variable at Origin of the Lift (H1)	43cm
2	Horizontal Task Variable at Destination of the Lift (H2)	43 cm
3	Verticle Task Variable at Origin of the Lift (V1)	25cm
4	Verticle Task Variable at Destination of the Lift (V2)	190cm
5	Asymmetric Angle at the Origin (A1)	0
6	Asymmetric Angle at the Destination (A2)	20
7	Verticle Lift (D)=V2-V1	165cm
8	Frequency of Lifting (F)	10
		lifts/min
9	Duration of the work (Dur)	<1 hour
10	Type of Coupling (C)	Good

Enter the following data Load to be lifted---

```
5
Horizontal Distance at origin---
43
Horizontal Distance at Destination---
43
Vertical Distance at Origin---
25
Vertical Distance at Destination---
190
Frequency i.e, Lifts per Minute---
10
Asymmetric Angle at Origin---
0
Asymmetric Angle at Origin---
20
What is the type of Coupling
PRESS
1 for Good
2 for Fair
3 for Poor
1_
```



1
What is the Duration of Service
PRESS
1 for <=1 hour
2 for 1 to 2 hours
8 for 2 to 8 hours
1
MULTIPLIERS ARE AS UNDER
HM UM DM AM FM CM
0.5813950.850.84727310.451
0.58139500.8472730.9360.451
The Recommended Weight Limit(RWL1) at origin is 4.333652
$\pi_{1} = \pi_{2} + \pi_{2$
The Recommended Weight Limit(RWLZ) at Destination is 0
The lifting Index at animin in 1 4529(1
The TTLETHA THRex of OLIGTH T2. 1.122401
///The Lifting Index at the Dectination is INFINITE///
When the differing index at the bestination is infinite///

Fig. 3(b) — Multiplier calculations.

The lifting Index at origin is 1.153761 With Lifting Index at the Destination is INFINITE/// Lifting Index at the Destination SUGGESTIONS FOR THE REUISION Your horizontal reach is unsafe Ensure that the following measures must be taken: I. Renow the obstacles if any comes in between the worker and the pick/place baction order about the following measures must be taken: I. The overtael height of standings on the Yoay mark at the time of lifting d. Measure that the following measures must be taken: I. The overtael height is overtael distance from the lifting station to the hand submet had the ores last the tables with adjustible heights must be used about the following measures must be taken: I. The overtael height of the tables with adjustible heights must be used applying the lift with 360 degrees rotating table so that the used such as paller lift with 360 degrees rotating table so that the ourber as desire ad dust the lift by just using a hydraulic pumps pedal LIFTING IS MAZARDOUS AT THE DESTINATION 'REVISIONS TO BE DONE' SUGGESTIONS FOR THE REVISION 'Reveal and and the come less than 25cme 'Make an indicator on the floor (painted thick lines) and make sure that the use here and here substacles if any comes in between the worker and the pick/place inform the horizontal distance between the hands and the shoulder of the u worker advesce babitual of standingon that very mark at the time of lifting 'Researce the obstacles if any comes in hetween the worker and the pick/place 'Note and indicator on the floor (painted thick lines) and make sure that the use of the data sure that the come less than 25cme 'Your Wern Vertael Measure that the come less than 25cme 'Your Wern the horizontal distance between the worker and the pick/place 'Note an indicator on the floor (painted thick lines) and make sure that the use here horizontal	
<pre>///The Lifting Index at the Destination is INFINITE/// LIFTING IS HAZARDOUS AT THE ORIGIN 'REUISIONS TO BE DONE' SUGGESTIONS FOR THE REUISION Your horizontal reach is unsafe Fig. 3(c) — Recommendations for unsafe lifting at the origin the heave that the following measures must be taken: The vertical height is and the pick/place to be obstacles if any comes in between the worker and the pick/place to be obstacles if any comes in between the worker is the time of lifting the autor the horizontal distance for unsafe lifting at the origin. Fig. 3(c) — Recommendations for unsafe lifting station to the hand should lie in between workers must be taken: I the worker had being the is using a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE REDISION Your horizontal reach is unsafe Ensure that the following measures must be taken: I the surface for the following measures must be taken: I the worker had being the ison to be taken: I the worker had being the ison to be taken: I the worker for the REDISION Surgesting for the REDISION Your horizontal reach is unsafe Ensure that the following measures must be taken: I heave the obstacles if any comes in between the worker and the pick/place worker had only on the floor (painted thick lines) and make sure that the worker adcore habitual of standing on that very mark at the time for iffing the assure the horizontal distance for unsafe lifting at the origin desarrow in indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standing on that very mark at the time of lifting the assure the horizontal distance for the shoulder of the v worker becomes habitual of standing on that very mark at the time of lifting the assure the horizontal distance form the hands and the shoulder of the v worker becomes habitual of standing on that very mark at the time of lifting the assure the horizontal distance form the hifting station to the hand sho</pre>	The lifting Index at origin is 1.153761
LIFTING 15 HAZARDOUS AT THE ORIGIN 'REVISIONS TO BE DONE' SUGGESTIONS FOR THE REVISION Your horizontal reach is unsafe Ensure that the following measures must be taken: A may an indicator on the floor (painted thick lines) and make sure that the unders backmean balance and that the overtime the under back of the unders because the obstacles if any cones in between the unders have the time of lifting 2. Mark an indicator on the floor (painted thick lines) and make sure that the unders backmean balance and that the overtime form the lifting station to the hand to hould lie in batters underse must be taken: I. The vertical height is distance from the lifting station to the hand to hould lie in batters underse must be taken: I. The vertical height is distance from the lifting station to the hand to hould lie in batters underse must be taken: I. The vertical height is distance from the lifting station to the hand to hould lie in batters underse must be taken: I. The vertical height is distance from the lifting station to the hand to hould lie in batters underse must be taken: I. The vertical height is distance from the under height Describted. It is underse that the tables with adjuctible heights must be used the any djuct the lift by just using a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE DESTINATION 'REVISIONS TO BE DONE' SUGGESTIONS FOR THE REVISION Your horizontal reach is unsafe Ensure that the following measures must be taken: I. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the shear and make sure that H cones less than 25cm Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. I. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the unders of the vorker and the scenes location to the hand should be in between workers endthing on	///The Lifting Index at the Destination is INFINITE///
SUGGESTIONS FOR THE REVISION Your horizontal reach is unsafe Ensure that the following measures must he taken: Anark an indicator on the floor Quainted thick lines? and make sure that the location Thank an indicator on the floor Quainted thick lines? and make sure that the unset become habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the vorker and alke sure that if cones less than 25cm Fig. 3(c) — Recommendations for unsafe lifting at the origin. Ensure that the following measures must be taken: 1. The vertical height is vertical distance from the lifting station to the hand summe we that the following measures must he taken: 1. The vertical height is vertical lifting and shoulder height 2. The sature of the vertical height station to the hand summe we that the following measures must he taken: 1. The vertical height shoulder both adjustible heights must be used such as palled lift which 360 degrees votating table so that the vorker as desined any djust the lift by just using a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE REVISION Your horizontal reach is unsafe Prevent be obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor Quainted thick lines? and make sure that the worker becomes habitual of standingon that very mark at the time of lifting other becomes habitual of standingon that very mark at the time of lifting other betakens <	LIFTING IS HAZARDOUS AT THE ORIGIN 'REVISIONS TO BE DONE'
Your horizontal reach is unsafe Fig. 3(c) — Recommendations for unsafe lifting at the following measures must be taken: In vertical mark sure that the following measures must be taken: In vertical mark sure that borizontal distance between the worker and the pick/place location Gausker here horizontal distance between the hands and the shoulder of the u orker and make sure that the consel lifting of the u orker and make sure that the discover here horizontal distance from the lifting station to the hand so the taken is the vertical height is a vertical distance from the lifting station to the hand so the difference between the two vertical reaches is be infinal possible3. It is suggested that the tables vita adjustible height sure that the difference between the two vertical reaches is be infinal possible3. It is suggested that the tables vita adjustible height sure the vertical height shall not exceed 175cm. The maximu vertical height shall not exceed 175cm. The norizontal reach is unsafe Ensure that the following measures must be taken: Intervention of the REUISION Your horizontal reach is unsafe Ensure that the following measures must be taken: Intervention of the floor Quainted thick lines? and the pick/place location Power be obstacles if any comes in between the worker and the pick/place location Index were the horizontal distance petween the hands and the shoulder of the vorker and hake sure that the core less than 25cm. Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. I. Renove the obstacles if any comes in between the worker and the pick/place location 2. A measure the horizontal distance petween the hands and the shoulder of the vorker and make sure that the comes less than 25cm. Fig. 3(d) — Recommendations for unsafe lifting station to the hand should be about the comes less than 25cm. YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOVED LIHIT <p< td=""><td>SUGGESTIONS FOR THE REVISION</td></p<>	SUGGESTIONS FOR THE REVISION
<pre>Your horizontal reach is unsafe Fnouve that the following measures must be taken: 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the 3. Wessure the horizontal distance between the hands and the shoulder of the v orker and make sure that W cones less than 25cms Fig. 3(c) — Recommendations for unsafe lifting at the origin. Ensure that the following measures must be taken: 1. The vertical height 1.e vertical distance from the lifting station to the hand e hould le in between workers matching and houlder height 2. Make sure that the difference between the two vertical reaches is be mininal possible3. It is suggested that the tables vith adjustible height must be used used may duit the lift by just using a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE DESTINATION 'REUISIONS TO BE DONE' SUGGESTIONS FOR THE REUISION Your horizontal reach is unsafe Ensure that the following measures must be taken: 1. Renove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the uorker and anke sure that H cones less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Renove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the uorker and make sure that H cones less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Remove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the location 2. Mark maning the pick of the difference between the hands and the shoulder of the u orker and make sure that H cones less than 25cms Fig. 3(d) — Recommendations for unsafe lifting station to the hand should lie in between wor</pre>	
Ensure that the following measures must be taken: 1. Renove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker hecomes habitual of standingon that very mark at the fine of lifting 3. Reasure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms Fig. 3(c) — Recommendations for unsafe lifting station to the hands should is in between the distance from the lifting station to the hands should be in between uorkers midthigh and shoulder height 2. The maximum vertical height shall not exceed 175cm. 3. Make sure that the difference between the two vertical peaches is be minimal pesibled. It is suggested that the tables uith adjustible heights must be used such as pallet lift vitha 360 degrees rotating table so that the worker as desir ed may djust the lift by just using a hydraulic pumps pedal LIFTING IS MACARDOUS AT THE DESTINATION 'REUISIONS TO BE DONE' SUGGESTIONS FOR THE REUISION 	Your horizontal reach is unsafe
Jecation 2. Mark an indicator on the floor (painted thick lines) and make sure that the uorker hecones habitual of standingen that very mark at the fine of lifting 3. Resource the horizontal distance between the hands and the shoulder of the v orker and make sure that H cones less than 25cns Fig. 3(c) — Recommendations for unsafe lifting at the origin. Ensure that the following measures must be taken: 1. The vertical height i.e vertical distance from the lifting station to the hand should be in between uorkers midthigh and shoulder height 2. The maximum vertical height shall not exceed 175cn. 3. Make sure that the difference between the two vertical peaches is be minimal possibled. It is suggested that the tables uith adjustible heights must be used such as pallet lift vitha 360 degrees rotating table so that the worker as desir ed may djust the lift by just using a hydraulie pumps pedal LIFTING IS MAZARDOUS AT THE DESTINATION 'REUISIONS TO BE DONE' SUGGESTIONS FOR THE REUISION Your horizontal reach is unsafe Ensure that the following measures must be taken: 1. Renove the obstacles if any cones in between the uorker and the pick/place location 2. Mark an indicator on the floor Quainted thick lines) and make sure that the orker and make sure that H cones less than 25cns Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Renove the obstacles if any cones in between the uorker and the pick/place location 2. Mark an indicator on the floor Quainted thick lines) and make sure that the uorker and make sure that H cones less than 25cns Fig. 3(d) — Recommendations for unsafe lifting station to the hand an indicator on the floor Quainted thick lines) and make sure that the uorker he original distance between the hands and the 'shoulder of the v orker and make sure that H cones less than 25cns YOUR UERTICAL REACH HAS CROSSED THE MAXIMUM ALLOVED LIMIT Your vertical reach. is UN	Ensure that the following measures must be taken: 1. Remove the obstacles if any comes in between the worker — and the pick/place
 Fig. 3(c) — Recommendations for unsafe lifting at the origin. Ensure that the following measures must be taken: The verteal height is evertical distance from the lifting station to the hand schuld lie in between vorkers nidthigh and shoulder height The maximum vertical height shall not exceed 175cn. Thake sure that the difference between the two vertical reaches is be nininal possible3. It is suggested that the tables with adjustible heights must be used uch as pallet lift witha 360 degrees rotating table so that the vorker as desired and plust the lift by just turing a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE DESTINATION 'REVISIONS TO BE DONE' SUGGESTIONS FOR THE REVISION Your horizontal reach is unsafe Ensure that the following measures must be taken: Remove the obstacles if any cones in between the worker and the pick/place location Make sure that I cones less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. Remove the obstacles if any cones in between the worker and the pick/place location Maximum the following measures must be taken: Remove the obstacles if any cones in between the worker and the pick/place location I. Remove the obstacles if any cones in between the worker and the pick/place location Maximum the following measures must be taken: Remove the obstacles if any cones in between the worker and the pick/place location Maximum the vertical distance between the hands and the shoulder of the worker and make sure that H cones less than 25cms Fig. 3(d) — Recommendations for unsafe lifting station to the hand so the worker and make sure that H cones less than 25cms Your vertical reach is UNSAFE Ensure that the following measures must be taken: He workish height is vertical distance from the hifting stati	location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the w orker and make sure that H comes less than 25cms
Ensure that the following measures must be taken: 1. The vertical height i.e vertical distance from the lifting station to the hand should lie in between workers main high and shoulder height 2. The same that the different hit not not the superstrial reaches is be ninnal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift with 360 degrees rotating table so that the worker as desir ed may djust the lift by just using a hydraulic pumps pedal LIFTING IS HAZARDOUS AT THE DESTINATION 'REWISIONS TO BE DONE' SUGGESTIONS FOR THE REWISION Your horizontal reach is unsafe Ensure that the following measures must be taken: 1. Remove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the u orker and make sure that H comes less than 25 cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Remove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25 cms Fig. 3(d) — Recommendations for unsafe lifting station to the hand should of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H cones less than 25 cms YOUR VERIICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand should lie in between workers midthigh and shoulder heigh	Fig. 3(c) — Recommendations for unsafe lifting at the origin.
LIFTING IS HAZARDOUS AT THE DESTINATION 'REVISIONS TO BE DONE' SUGGESTIONS FOR THE REVISION Your horisontal reach is unsafe Ensure that the following measures must be taken: I. Remove the obstacles if any cones in between the worker and the pick/place location 2. Mark in indicator on the floor (painted thick lines) and make sure that the worker heromes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Remove the obstacles if any cones in between the worker and the pick/place location 2. Mark and ficator on the floor (painted thick lines) and make sure that the worker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Remove the obstacles if any cones in between the worker and the pick/place location 2. Mark and ficator on the floor (painted thick lines) and make sure that the worker and make sure that H cones less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MARINUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand should lie in between workers midthigh and shoulder height 2. Mark sure that the difference between the two vertical reaches is be minimal possible. It is uggested that the taken is that using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum vertical height bealt not sure as desire at may dust the lift by just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand s should lie in between vorkers nidthigh and shoulder height 2. The maximum vertical height shall not exceed 175cm. 3. Make sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift witha 360 degrees rotating table so that the worker as desin ed may djust the lift by just using a hydraulic pumps pedal
SUGGESTIONS FOR THE REUISION Your horizontal reach is unsafe Ensure that the following measures must be taken: 1. Remove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Remove the obstacles if any comes in between the worker and the pick/place location 3. Measure the horizontal distance between the worker and the pick/place location 3. Measure the horizontal distance between the worker and the pick/place location 3. Measure the horizontal distance between the hands and the shoulder of the worker and make sure that H comes less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The worker had the difference between the two vertical reaches is be minimal possible3. It is suggested that the taken the two vertical reaches is be minimal possible3. It is for uggested that the taken the use vertical reaches is be minimal possible3. It is using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum vertical height sults and shorular be so that the worker as desire ed nay dust the lift by dus	LIFTING IS HAZARDOUS AT THE DESTINATION 'REVISIONS TO BE DONE'
 Your horizontal reach is unsafe Ensuve that the following measures must be taken: Renove the obstacles if any cores in between the worker and the pick/place location Maxia indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the vorker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. Remove the obstacles if any cores in between the worker and the pick/place location. Remove the obstacles if any cores in between the worker and the pick/place location. Remove the obstacles if any cores in between the worker and the pick/place location. Remove the obstacles if any cores in between the worker and the pick/place location. Resoure the horizontal distance between the hands and the shoulder of the vorker and make sure that H cores less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOVED LIMIT Your vertical reach is UNSAFE The worker that the following measures must be taken: The workar her following measures must be taken: The workar has sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the taken work with a distribute heights must be used auch as pallet lift with 368 degrees rotating tables to that the worker as desire ef any duut the lift by just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) —	SUGGESTIONS FOR THE REUISION
 Your horizontal reach is unsafe Ensure that the following measures must be taken: Renowe the obstacles if any comes in between the worker and the pick/place Z. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the vorker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. Renowe the obstacles if any comes in between the worker and the pick/place location Renowe the obstacles if any comes in between the worker and the pick/place location Mark an indicator on the floor (painted thick lines) and make sure that the worker and make sure that H comes less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: The workand has the ofference between the taken the lifting station to the hand should be hight i.e. vertical distance from the lifting taking be minimal possible3. It is suggested that the take value take the difference between the two vertical reaches is be minimal possible3. It is suggested that the the distribute hights must be using a hydrawilic pumps pedal Your frequency of lifting is UNSAFE The maximum refield be SUNSAFE The maximum frequency i.e. lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	
Ensure that the following measures must be taken: 1. Renove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Renove the obstacles if any comes in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The overtcal height i.e vertical distance from the lifting station to the hand should lie in between workers midthigh and shoulder height 2. The maximum vertical height hall not exceed 172c. 3. Hake sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the takets with adjustible heights must be used such as pallet lift with 36d degrees rotating tables of that the worker as desire ded may dust the lift by Just using a hydrawile pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	Your horizontal reach is unsafe
 location 2. Mark an indicator on the floor (painted thick lines) and make sure that the uorker bacones habitual of standingon that very mark at the time of lifting 3. Measure the heads and the shoulder of the vorker and make sure that H comes less than 25cms Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the origin destination. 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker heromes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the worker and make sure that H comes less than 25cms YOUR VERITCAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The overtcal height i.e worker shall not exceed 175cm. 3. Hake sure that the difference between the taken! 3. Hake sure that the difference between the two vertical reaches is be minimal possible. It is owned shall not exceed 175cm. 3. Hake sure that the difference between the two vertical reaches is be minimal possible. It is over the the the difference between the two vertical reaches is the using a hydrawilic pumps pedal Your frequency of lifting is UNSAFE The maximum vertical height be worker solid distance from the lights must be used such as pallet lift by Just using a hydrawilic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destinatio	Ensure that the following measures must be taken: 1. Remove the obstacles if any comes in between the worker $\$ and the pick/place
 Fig. 3(d) — Recommendations for unsafe lifting at the origin destination. 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the floor (painted thick lines) and make sure that the floor (painted thick lines) and make sure that the floor orker and make sure that the cones less than 25cms YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand shoulder height 2. The maximum vertical height the take the taken the take distribute heights must be taken and have sure that the difference between the two vertical reaches is be minimal possible. It is surgested that the take with adjustible heights must be used and have all of the softward the should be should be in the verter as desired and have all of the softward the softward the softward be should be softward the softward between a softward the softward between a softward betward between a softward between	location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker amd make sure that H comes less than 25cms
 destination. 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the floor (painted thick lines) and make sure that the floor of the very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the v orker and make sure that H comes less than 25cms YOUR VERIICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand shoulder height 2. The maximum vertical height that the taken is based on the distance between the two vertical reaches is be minimal possible. It is supested that the the difference between the two vertical reaches is be minimal possible. It is using a hydrawlic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination. 	Fig. $3(d)$ — Recommendations for unsafe lifting at the origin
 Renove the obstacles if any cones in between the worker and the pick/place location Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting Measure the horizontal distance between the hands and the shoulder of the worker and make sure that H comes best hands and the shoulder of the worker and make sure that H comes between the hands and the shoulder of the worker and make sure that H comes between the hands and the shoulder of the worker and make sure that H comes between the hands and the shoulder of the worker and make sure that H comes best hand 25cms YOUR UERIICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: The overtcal height i.e vertical distance from the lifting station to the hand s should lie in between workers midthigh and shoulder height The maximum vertical height hall not exceed 175cm. Hake sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that be takens with adjustible heights must be used such as pallet lift with 360 degrees rotating the so that the worker as desire and make used for the by UNENFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination. 	destination.
 1. Renove the obstacles if any cones in between the worker and the pick/place location 2. Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Measure the horizontal distance between the hands and the shoulder of the worker and make sure that H cones less than 25cms YOUR UERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: The worker and make sure that H cones less than 25cms YOUR UERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: The nextinum vertical height shall not exceed 175cm. The worker hat the difference between the two vertical heights The the difference between the two vertical heights must be used such as pallet lift within 360 degrees rotating the so that the worker as desire and may duut the lift by Just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination. 	
YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand is should lie in between workers midthigh and shoulder height 2. The maximum vertical height shall not exceed 175cm. 3. Make sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift witha 360 degrees rotating table so that the worker as desir ed nay djust the lift by just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	 Remove the obstacles if any cones in between the worker and the pick/place location Mark an indicator on the floor (painted thick lines) and make sure that the worker becomes habitual of standingon that very mark at the time of lifting 3. Heasure the horizontal distance between the hands and the shoulder of the w orker and make sure that H comes less than 25cms
Your vertical reach is UNSAFE Ensure that the following measures must be taken: 1. The vertcal height i.e vertical distance from the lifting station to the hand is should lie in between workers midthigh and shoulder height 2. The maximum vertical height shall not exceed 175cm. 3. Make sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift witha 360 degrees rotating tables so that the worker as desire ed may djust the lift by just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	YOUR VERTICAL REACH HAS CROSSED THE MAXIMUM ALLOWED LIMIT
Ensure that the following measures must be taken: I. The vertcal height i.e vertical distance from the lifting station to the hand is should lie in between workers midthigh and shoulder height 2. The maximum vertical height shall not exceed 175cm. 3. Make sure that the difference between the two vertical reaches is be minimal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift witha 360 degrees rotating tables so that the worker as desire ed may djust the lift by just using a hydraulic pumps pedal Your frequency of lifting is UNSAFE The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	Your vertical reach is UNSAFE
The maximum frequency i.e lifts per minute may be set to 8 Fig. 3(e) — Recommendations for lifting at the destination.	Ensure that the following measures must be taken: 1. The vertcal height is a vertical distance from the lifting station to the hand schould lie in between workers midthigh and schoulder height 2. The maximum vertical weights chall not exceed 275cm, 3. These sure that the difference between the two evertical reaches is be minimal possible3. It is suggested that the tables with adjustible heights must be used such as pallet lift witha 366 degrees rotating table so that the worker as desire ed may djust the lift by just using a hydraulic pumps pedal Vaux forwaren of liftics is NUMOPE
Fig. 3(e) — Recommendations for lifting at the destination.	The maximum frequency i.e lifts per minute may be set to 8
	Fig. 3(e) — Recommendations for lifting at the destination.

four frequency of fifteing is on and														
The	ma	ximur	n fre	equenc	y i.e	lift	s pe	r mir	nute	may	ье	set	to	8
¥O	UR Kin Or	WORKI DLY INDU(ER IS Reduc Ce Mo	S WORK CE THE ORE WO	ING F DURA RKERS	OR QU TION FOR	ITE OF THE	Long Work/ Same	PERI VINCL JOB	ODS UDE	I NA Res	A I T PA)AY IUSE	Ś
Do	you	want	t to	conti	nue									

Fig. 3(f) — Input for start and stop of the programme.

obtained which have been shown in screen shots obtained as an output of the executed programme from Fig. 3(a-f).

Figure 3a shows the first screen after execution of the programme where in it asks for various input data as mentioned in Table 1. Once the data is entered, the programme calculated different multipliers along with

Table 2	- Comparison of results	
Multipliers	Tables	Programme
HM1	0.58	0.581395
HM2	0.58	0.581395
VM1	0.85	0.85
VM2	0.0	0.0
AM1	1.0	1.0
AM2	0.94	0.936
DM	0.85	O.847
FM	0.45	0.45
CM	1.0	1.0
RWL(ORIGIN)==	4.38	4.334
RWL(DESTN)==	0.0	0.0
Lifting Index(Origin)=	5/4.38=1.14(unsafe)	5/4.334=1.15
Lifting Index(Destn)=	5/0=∞	(unsafe5/0=∞

RWL and LI as shown in Fig. 3(b-e) displays the safe and unsafe lifting index (LI), and based upon unsafe LI, it identifies the input parameters resulting in unsafe index. Followed by this, the programme also suggests safe recommendations which have to be incorporated on the site in order to create safe working environment. Figure 3f prompts user to select an option if he/she wants to continue or not.

5 Conclusions

The programme developed for the NIOSH lifting equation would prove to be the best tool for the wide spread applicability of the equation as it gives reliable results along with solution for the problem, if any. On the basis of output given by the computer programme, a safe lifting can be ensured. Depending upon the application and worksite conditions, various input parameters like horizontal distance (H), vertical location (V), frequency of lifting *etc.* are determined which are further used for computing lifting index which forms the criterion for creating safe work environment. The programme is tested for accuracy by comparing its results with theoretical calculations carried out using data for multipliers from standard tables as mentioned in NIOSH work practice guide. The comparison has shown negligible deviation in the results as shown in Table 2.

On the basis of lifting index, computer programme suggests recommendations/alternatives for various unsafe conditions, thereby making work environment safe. The user needs not to refer tables and go for lengthy exercises to find out the solutions to be implemented in order to safe guard the worker. This programme thus is a tool in the hands of the authorities to safe guards their workers so that overall productivity increases.

References

- 1 Garg A, *Plant Eng*, 37(1983) 67.
- 2 Hwang & Park, J Hum Eng Soc Korea, 11(1992) 3.
- 3 Kuwashima A, Aizawa Y, Nakamura K, Taniguchi S & Watanbe M, *Ind Health*, 35 (1997) 187.
- 4 Hoskins A F, Miller T A, Hanford W D & Landes S R, National Safety Council (1998) 30
- 5 Wang M J J, Garg A, Chang Y C, Shih Y C, Yeh W Y & Lee C L, *Hum Factors*, 40 (1998) 509.
- 6 Kermit G, Bryan C, Kirking L L G & Jaehwan Y, *Hum Factors*, 39 (1997) 312.
- 7 Patrick G. D, Int J Indus Ergon, 31 (2003) 11.
- 8 Yang S H, J Korean Inst Plant Eng, 20 (1997) 323.
- 9 Waters T R, Putz-Anderson V, Garg A & Fine L J, *Ergon*, 36 (1993) 749.
- 10 Waters T R & Putz-Anderson, *Health Haz Eval Report*, 93 (1995) 0920-2548.
- 11 Waters T R, Lu M L & Occhipinti E, Ergon, 50 (2007) 1761.
- 12 Min K C & Dohyung K, Int J Indus Ergon, 25(2000) 423.
- 13 Henry G & Nelson G, Nelson & Associates-Consultants (1995).
- 14 Hidalgo J, Genaidy A, Karwowski W, Christensen D, Huston R O N & Stambough J, *Ergon*, 38 (1995) 2455.
- 15 Patrick G D, Ergon, 45 (2002) 817.
- 16 Hameed A Z & Basahel A M, J Sci Indus Res, 78 (2019) 199.
- 17 Zubar H A & Alamoudi, R, J Sci Indus Res, 78 (2019) 144.
- 18 Halder S J, Rasheed F, Jeong B J & Kim W, J Sci Indus Res, 75 (2016) 28.
- 19 Nobakht N, Askari M, Nikbakht A M & Ghorbani Z, J Met Soc India, 32 (2017) 311.
- 20 Suwandi A & Hermawanto D, J Met Soc India, 27 (2012) 295.
- 21 Meepradit P, Sunee N & Chantrasa R, *J Biosciences Med*, 3 (2015) 39.
- 22 Sharma S M, Singh S, Singh B, Javaid M & Asjad M, Int J Proc Man, 9 (2016) 659.
- 23 Health Division of Biomedical & Behavioral Science, Nat Inst Occup Safety and Health, (1981) 81.