A Knowledge-Based System for Ergonomic Application in Indian Manufacturing Industries (KBSEAM)

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Abstract

In this work, the author developed a knowledge-based system for ergonomic application in manufacturing (KBSEAM) which is helpful to solve the ergonomic related issues in small and medium scale manufacturing organizations. Generally, budding entrepreneurs have very limited knowledge about the application of the ergonomic tool in the manufacturing sector. This software is introduced to create this awareness and to make them initiate the use of these ergonomics tools their industries. This software guides the users in understanding the fundamentals of ergonomics and also helps a new entrepreneur in providing the guidelines for considering ergonomic issues in a unit for small and medium-scale organizations. The software provides the various ergonomic assessment tools which can be used to assess the ergonomic issue prevailing in the workers during work such as MSDs, Strain on worker mental health and safety issues. Furthermore, a case study of an Indian Saw-mill is taken to assess the working condition of the worker during work and relative actions were suggested to rectify the work methods.

Keywords
Ergonomics, Knowledge-based system, Manufacturing industries and assessment tools.

1. Introduction

In many developing countries several startups that are coming up in which small and medium scale industries are more in number. These small scale industries strive to become more and more productive to accomplish their vision and develop in the future. To achieve these long term objectives, the companies have to adapt and design a unique plan of action. One among them is the wellbeing of human resource, which is an important aspect of the industries nowadays. The workplace portrays in the performance of human resources. If the workplace is not designed as per the human comfort and requirements of the task, it may lead to poor performance and results in the occurrence of an undesired work-related problem.(Sonasale Priti, et.al 2017, Sonasale Priti,et al 2016). Hence the companies must concentrate on the design of workspace as per human comfort and task requirement. This could be better understood and analyzed by the application of ergonomics at different levels in the industries. International Ergonomics Association (IEA) (2000) defines ergonomics as "Ergonomics is the scientific discipline concerned with the fundamental understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance". Ergonomics can be applied at various levels in the manufacturing sectors starting from planning till the delivery of the product as shown in Figure 1. Here the paper focuses on the development of an expert system to apply the ergonomic tool in the manufacturing sector. The foremost objectives of the expert system are to guide the user about the importance of ergonomic concepts and to inform the user of unacceptable factor constraints. The dual aims of the *KBSEAM* system are therefore to provide the ergonomics novice with the detailed guidance he requires and yet allow the more experienced user the autonomy to move freely around the system examining such areas as he thinks fit when he thinks fit. To cater for both the expert and novice users, the expert system has to be organized into many different levels.

Figure 1: Application of ergonomics in the workplace (IEA)

2. Literature Review

A range of papers have provided the impending benefits obtained from using expert systems to help out in ergonomic design. The various authors have demonstrated these benefits using some knowledge bases containing ergonomics expertise in conjunction with the expert system. However, the expected level of application of ergonomics in manufacturing systems is yet to be achieved, since the complete information about ergonomics standards and data is not available. An extensive survey that was carried out as a part of the proposed work revealed that there is a need for ergonomics related information and data, and also significant issues related to the application of ergonomics in manufacturing organizations. This literature review also guides the author to recognize a tactic to build up a computer-assisted system for ergonomics which is proposed in the current paper. The developed system is expected to enhance the level of application of ergonomics knowledge and data in manufacturing systems, and results in safe and healthy working conditions and also increase in quality of work and productivity.

Artificial intelligence has a broad classification and expert system is a part of it. It was introduced in 1960 and the major focus was on transferring specific task expertise from humans to machines. An Expert system is a branch of artificial intelligence in which the knowledge of the specific task is fed to the computer and is stored. This stored knowledge is retrieved and used in the form of specific suggestions for a specific problem through the help of software which creates the interface to consult and interact with the user. The developed system will be flexible to provide the solution for specific work-related issues that are already stored in the computer. These knowledge-based systems guide the user to make certain decisions in solving their problems. Shu-Hsien, L.(2005), Sonasale Priti, et.al (2021). Ashraf Shikdara et al (2002) have developed an ergonomic self-assessment tool for the manufacturing industry to evaluate ergonomic improvement potential of production systems in the shop floors. This helped them to formulate strategies to improve the ergonomic conditions in their industries. Robert Feyen et al (2000) have developed a software tool that could perform the ergonomic analysis of workplace design at the initial stages to avoid the biomechanical risk and injuries that occurred while performing efficient and friendly interface design. Jen-Gwo Chen, R. E. (1991),Qutubuddin S.M.et.al (2012). A knowledge-based expert system technique is applied to evaluate the different ergonomic causes that lead to predispose to a low back disorder. The outcome of the work is utilized in determining the causes that are desired to be restricted as a precautionary measure Osama Abdel et.al (2011). An expert system was developed using the fuzzy logic concept to assess the performance of HSE and ergonomic system factors. The developed system is very robust and is helpful for continuous assessment and improvement in the gas refinery.Azadeh, I. F. (2008). An adaptive intelligent algorithm is developed using artificial neural network and fuzzy logic. This algorithm is used to forecast and improve the mental workload among operators concerning HSEE in large gas Treatment Company. This work has helped managers to foresee if operators are satisfied with their mental workload in the context of HSEE. Azadeh, M. R. (2013). A knowledge-based system called "tool expert" is developed that provides understandable and crisp guidelines for selecting, designing and using hand tools for particular jobs that could avoid the acute chronic stress experienced by the workers. It helps to have better working conditions and improves the morale of the work. Charoenchai, B. K. (2004). A rule-based expert system is developed to support physicians to make decisions during diagnosis. This expert system considers the database in which similar data sets are available and it compares and guides the physician in making a decision. V.Mahesh, A. (2009), Qutubuddin S.M (2012)

3. Methodology

KBSEAM is proposed for Indian manufacturing industries to solve the ergonomics issues prevailing in their industries. The contemplation is to develop a user-friendly software using a C# programming language in Microsoft Visual Studio 2010. First, the data is collected from many sources such as journals, handbooks, books, article; website etc. The inputs from the data are studied and ergonomics issues related to Indian industries are identified. To make the system robust and reliable, the data is considered for only small and medium scale manufacturing organizations. Initially, a basic outline is of the KBSEAM system is realized. Furthermore, the various modules are the work. It predicts the 3D static strength in the automotive assembly line using 3DSSPP software. Few authors have worked on the development of an interactive computer-assisted Ergonomics Analysis System to evaluate the task and investigate the problem situations evolved in manual material handling tasks. These were analyzed by using EIAS, PWSI and DLAS menus designed as per the requirement of the users as shown in Figure 2.

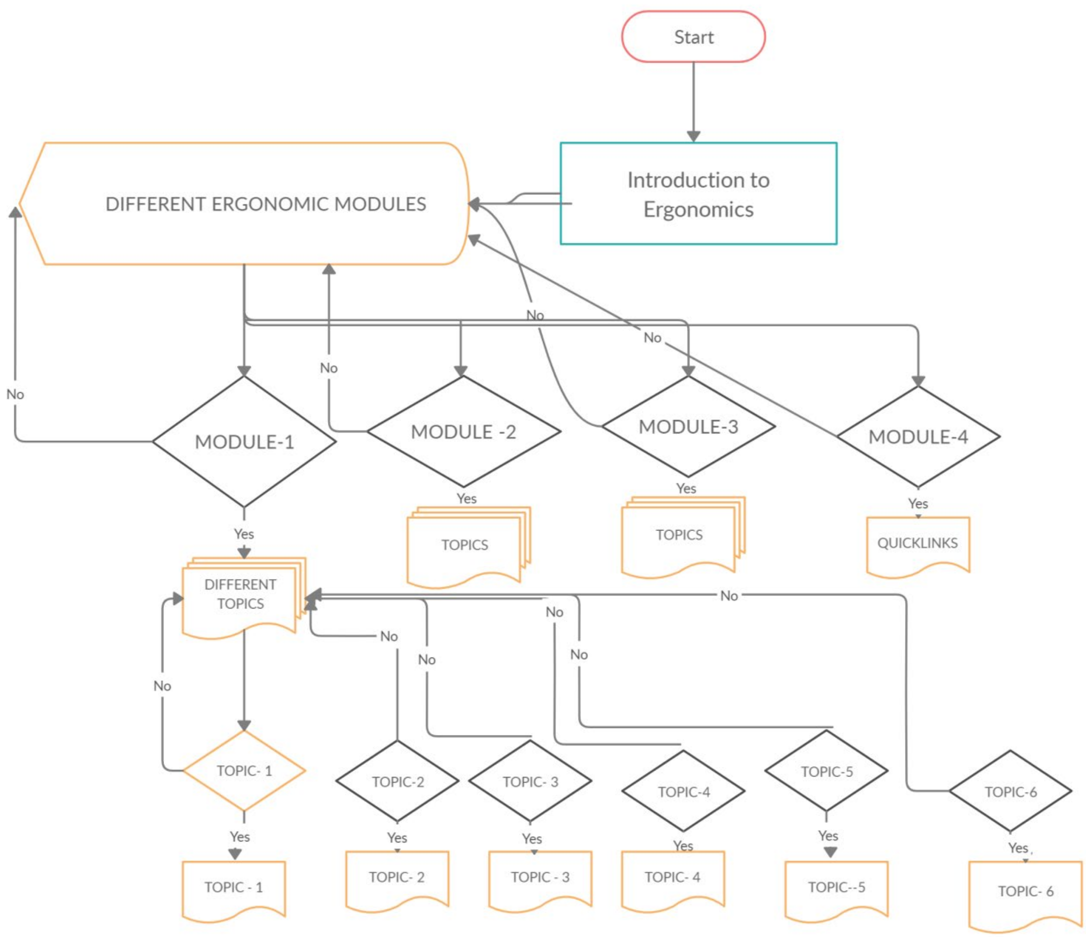

Figure 2: Basic outline of the KBSEAM

Further, the data is studied for its relevance and its usability in software developed is analyzed. Four main modules are planned, each having a particular set of information essential for its implementation time- to- time.

3.1 Various modules in KBSEAM

The initial interface gives brief information about the ergonomics in general. One side of the interface contains the brief information and another side of the interface has the titles of the modules in the form of a list. Each module is designed to provide particular information about the ergonomics. The user can click on the title of the module to open the interface of that particular module. There is also a Back Button provided to revisit the first page.
Module 1 is designed to educate the user and novice about the fundamentals of the ergonomics. The basic awareness is created in the user to think know-how of ergonomics in their industries.

Module 2 provides information about the standards and guidelines essential in the industries. Many guidelines and standards are available in the literature. The guidelines and standards necessary for the day-to-day task of the industries are only considered. These guidelines are segregated into items as per the task and user requirements. The user may require in-depth information about the particular ergonomic issue and then click on the particular item in the guideline to understand it and its implementation in work.
Suppose, a worker is facing MSD's while lifting a load of 15 - 20kgs. It is considered as one of the ergonomic issues in that particular industry. To cater to this issue, the guidelines are provided in the item "POSTURES". It contains the necessary guidelines while lifting the load. It guides the user to understand and implement the correct way of lifting the load to minimize the MSDs occurring during work. Similarly, many such guidelines necessary to carry out day-to-day activities in the industries are provided in this module.

Module 3 includes few intervention tools to assess the reason for the ergonomic issue in the workplace. Each ergonomic intervention tool has assessment steps. The user can consider a particular activity at the work. Divide the activity into many tasks and then select the appropriate intervention tool. Click on the title of the intervention tool, a new interface opens, which contains the step-by-step procedures to follow in implementing the tool. The user can always use the excel sheet developed by Alan Hedge (2001) provided as a link, which is easy to assess and calculate the risk involved while performing the task.

Once the user identifies the tasks involving higher risk, he can use the guidelines to make the rectification or alteration in the work, workplace or work holding device. Later, once again the task analysis is carried out to ensure whether the risk is still prevailing in the task for further changes in the work or workplace. To make this knowledge-based system a robust system, quick-links are designed. These links are helpful to dig deeper into the ergonomics interventions to have a better understanding of ergonomics and its intervention tools. Many quick-links are taken from different sources to provide the users with a better and comfortable platform to learn, understand, to interpret and to intervene in the ergonomic issues prevailing in the small and medium scale organizations

4. Validation of the Software

To realize the effectiveness of the developed KBSEAM, a case study of sawmill is considered and is carried out by Qutubuddin et al., one of the authors in this work. Anas Ali et.al, (2012).

4.1 Participant

Sawmill of the north Karnataka region is a highly unorganized sector in which thousands of workers are performing the various tasks. There is no sufficient data is available to analyze and assess the reasons for injury and accidents occurring at the workplace.. Most work is carried out manually as there are only few tools available to perform various tasks. These workers are exposed to saw dust while performing cutting operations which can cause respiratory issues. The major issue is the musculoskeletal disorders occurred while performing work. Most workers are hired on daily wages basis and are not assigned with a particular task every day and task may vary depending on the requirements of the task completion. Participatory ergonomics is considered for observation and data collection. Burgess-Limerick, R. (2018). Sawmill workers are interviewed in regard to their work, working conditions and level on MSDs they come across while performing various tasks. It was realized that 80% of the workers were suffering from various MSDs such as pain in thighs, limbs and around 50% of them with shoulders and arms. Table 1 shows the anthropometric details of sawmill workers. Sawmill remain open for 6 days in a week and the average working hours were 10 to 12 hours per day. On an average 2 workers remain absent in a week.

Table 1: Anthropometry of Sawmill worker for n=30

Sl.No	Parameter	Mean (Standard Deviation)
1.	Height of worker in cm	164.40 ± 3.65
2.	Age of worker in Years	34.2 ± 7.51

4.2 Procedure to determine discomfort level

Nordic questionnaire is used for analyzing the discomfort levels and MSDs in the Sawmill workers. Table 2 shows the discomfort levels in different organs of the sawmill workers.

Table 2: Discomfort levels in the various organs of Sawmill workers

Various organs of workers	Intensity of pain in %
Back	87
Hand	20
Shoulder	14
Wrist	23
Neck	22

4.3 Implementation of software to determine the solution

To overcome such discomfort level in the various organs of the sawmill workers, some ergonomics principles are implemented in the work and workplace. Particular task is considered and ergonomics principle is applied. Task such as workers lifting and carrying wooden logs from one place to another is considered for study which is as shown in Figure 2. As the task involves a lot of labour work and involves the MSDs and injuries such as pain in the neck, hand, wrist and shoulder, hence this task is considered for ergonomic analysis. Initially, fundamental of ergonomics is reviewed using module 1 of the software. After the review, the user can decide suitable ergonomics intervention tool to assess the level of risk involved in performing the task. In this task, the worker's body postures and the strain on the worker body is analyzed. From Figure 2 it is clear that both limbs and hands are involved in performing the task, hence REBA tool is appropriate to use is learnt from the software. Hedge, A. (2001), Hignett, M. (2000).

4.4 Evaluation using ergonomic assessment tool

To evaluate the level of risk involved in lifting and carrying the wooden logs from one place to another, REBA assessment tool is used. The steps involved in carrying out the REBA assessment are provided in the "Various assessment tools" module of the software. The user can download the assessment sheet and follow the steps as per instructions to determine the risk involved in performing the task. There is also an additional link provided at the bottom of the page in which the user can use an excel sheet developed by Alan Hedge. The user can click on the link to access and is easy to use and implement. This link is provided for the user having very limited knowledge about ergonomics. Hedge, A. (2001). Figure 4 shows the view of REBA worksheet.

Figure 3: Workers lifting the wooden logs

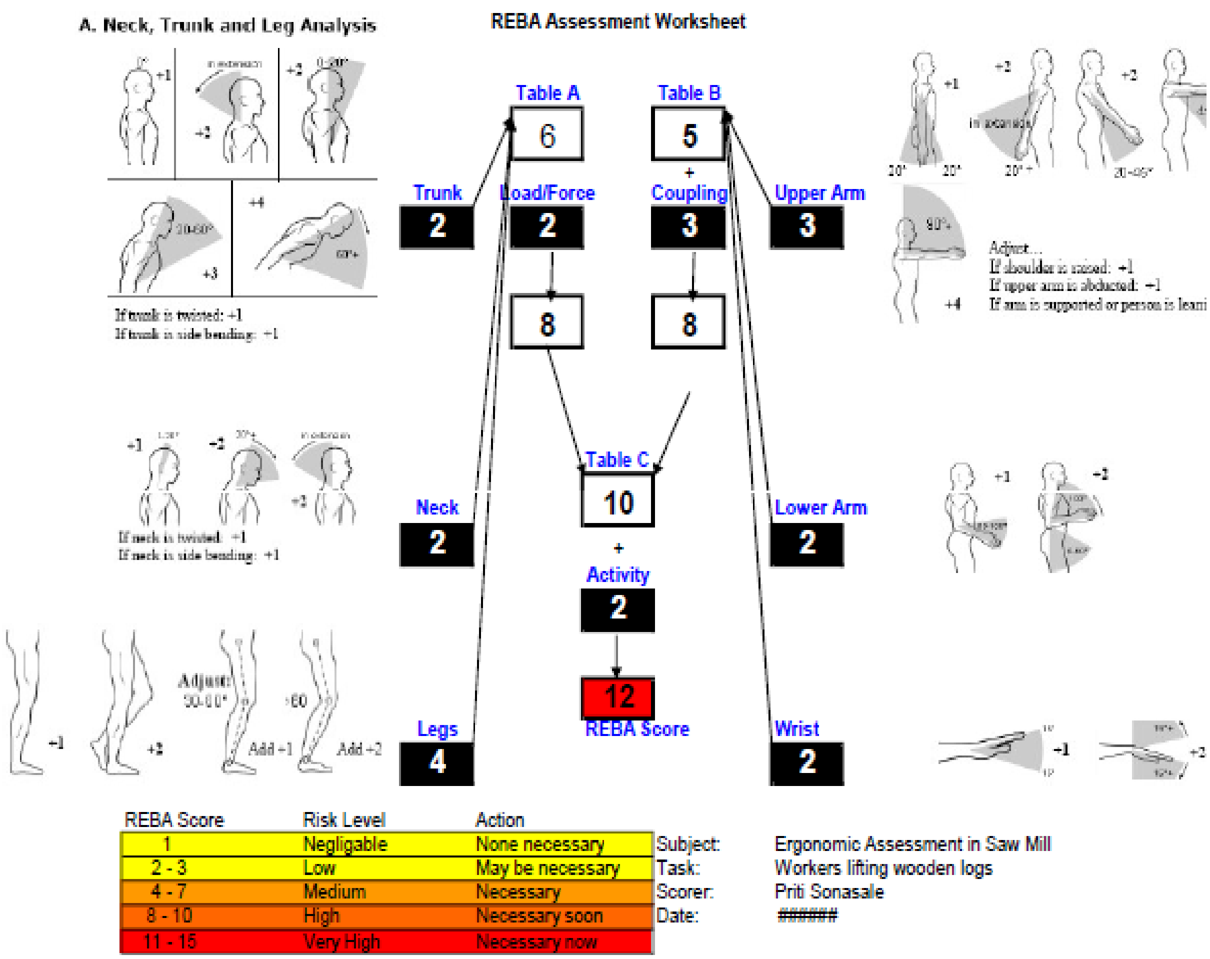

Figure 4: REBA Worksheet

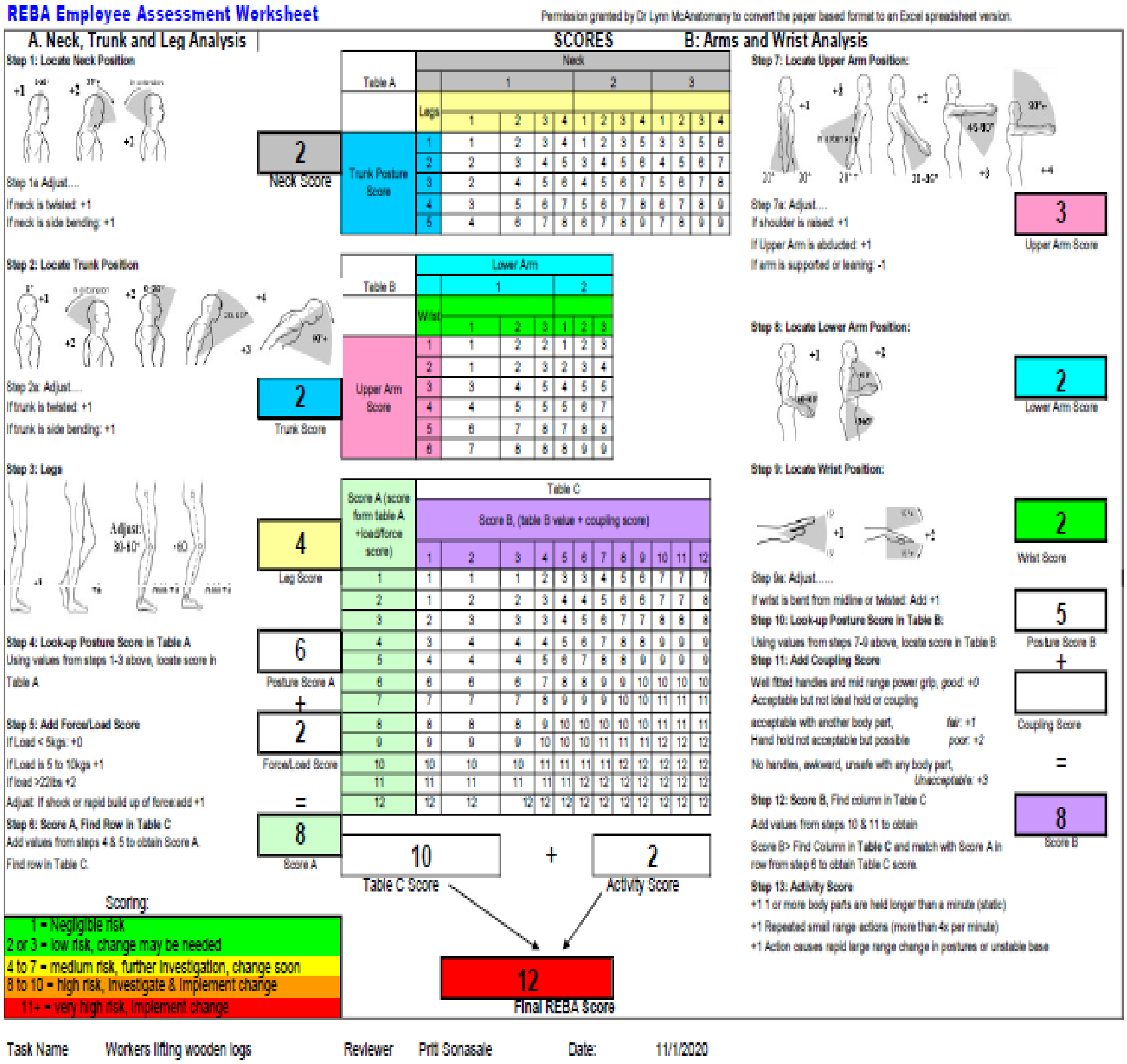

Figure 5: Detailed REBA Assessment sheet

From the above Figure 5, it is observed that, there is a very high risk involved in performing this task and needs to be changed immediately.

4.5 Determining Solution for the problem

This issue is resolved with the assistance of the developed software. The software KBSEAM has “Standards and guidelines” module, which is handy and is used to overcome this problem. Click on the Standard and guidelines, a new interface gets opened which contains two heading one is “Standards” and another “Guidelines”. Click on the guidelines heading, a dropdown menu opens which contain a section “Postures and Movements”. Furthermore, bring the cursor on “Postures and movements”, a dropdown subsection open which contains “Movements”, has the solution for this problem. In this subsection, few guidelines are provided for lifting and transporting the load from one place to another. From the sawmill perspective, there are many wooden logs have varying weights. As these loads are heavy and cannot be lifted manually hence a lifting and carrying devices or machines are more suitable to lift the loads. Loads of 700kgs and more can be easily lifted using mobile raising platform and can be transported from one place to another as shown in Figure 6. Other options such as fork lifter as shown in Figure 7 can also be used as per the convenience of the worker. Motorized trolleys can also be used depending on the type of floor and weight of the wooden logs. These lifting and transporting devices reduce the strain on the body parts especially on the hands and limbs of the worker while lifting and carrying the wooden logs. If any of the solutions are implemented at the workplace high risk of MSDs can be solved to a greater extent.

Figure 6: Mobile lifting Platform to lift and carry wooden logs

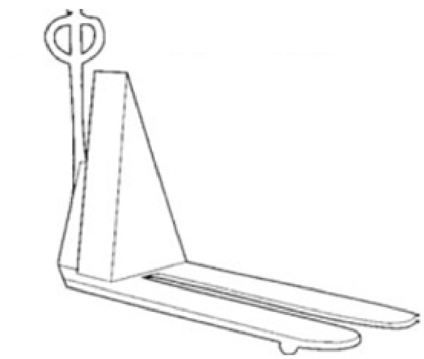

Figure 7: Fork Lift to lift and carry wooden logs

After using the mobile lifting platform and fort lift to pick-up and carry the wooden logs from one place to another place, the level of discomfort on the workers has reduced which is as shown in the Table 3

Table 3: Reduced Discomfort levels in the various organs of Sawmill workers

Various organs of workers	Intensity of pain in %
Back	30
Hand	40
Shoulder	10
Wrist	10
Neck	07

The REBA Worksheet is used to calculate the level of discomfort and strain on the workers. the figure 8 shows the REBA Worksheet after implementation of software. From the Figure 8, it can be seen that the risk is medium and the worker can perform the work easily with reduced discomfort and risk.

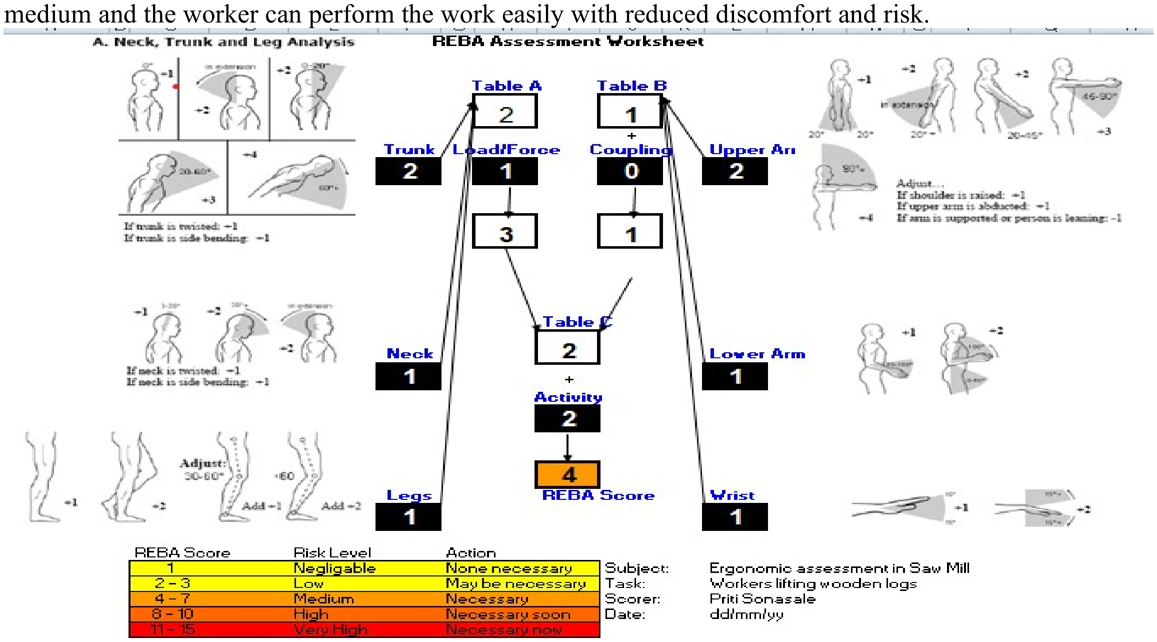

Figure 8: REBA Worksheet after implementation of software

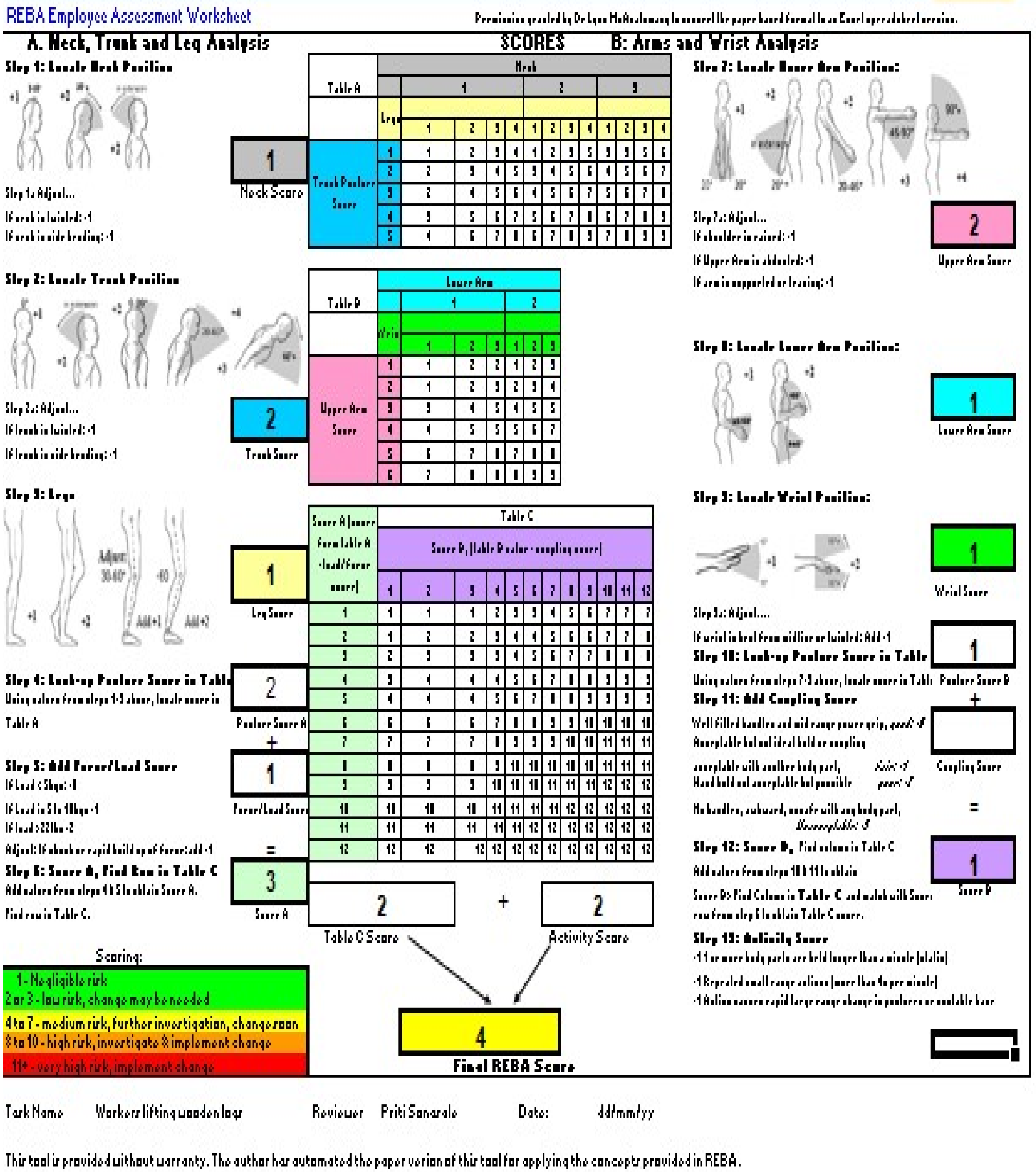

Figure 9: Detailed REBA Assessment sheet after implementation of software

5. Results and Discussion

By the application of KBSEAM, it can be seen that the entrepreneurs need not visit the various specialists to understand and root cause of the difficulties and evaluation methods at work and workplace. This developed software (KBSEAM) is one of its kinds which can not only offers necessary information about ergonomics but also provides various evaluation tools to assess each task and give the real time solution for the problems using the "guidelines" module. The developed knowledge-based system is self sufficient to understand interpret and evaluate the work. It also guides the user to come-up with better solution by using the standards and guidelines. Contrarily, there are only a few software's are available in the market which could help the user to give facilities such as understanding ergonomics, evaluation tools implementation and provide solution to the problem using the guidelines. To make it robust, quick links are provided so that the user can study variety of ergonomic issues occurring in industries.

In case of evaluation of MSDs in Sawmill work, REBA tool from the module "Various assessment tools" is used to assess the level of risk involved in performing the task. It contains step-by-step procedure as well as readymade excel sheets helpful to determine the level of risk while performing the various task. The figure 6 and figure 7 shows the final REBA core is "12", which is very high risk and the workers needs to change the postures immediately. This score is obtained before implementation the ergonomic guidelines from the software. The section "Movements" from "Standards and guidelines" module is used to give suggestion to the sawmill workers. This facility is rarely available in other software. Most of the existing software is designed to assess the ergonomic issues for particular industry such as garment industry, petrochemical industry where as KBSEAM software can be implemented in variety of small and medium scale manufacturing organizations to solve ergonomic issues of those industries. In most cases ergonomic experts are required to assess the work and workplace, whereas in this case KBSEAM software is used to assess the work and workplace.

The developed software not only provides the details about the issues at work, but also provides the necessary guidelines and solutions to correct the methods of performing the work. The Guidelines are implemented in the sawmill work and the REBA Score is calculate. The score obtained is "4" and is very low, which tells that there is medium risk in lifting and carrying the wooden logs using the mobile lifts and forklifts. Hence the mobile lifts and forklifts are implemented at the work. These lifters are used to have reduced discomfort and low risk while lifting and carrying the logs.

Limitations: KBSEAM software can be used only for small and medium scale manufacturing sector. The software needs to consider a variety of problems and its solutions. Hence more number of case studies has to be incorporated in the software to make it much more reliable and accurate.

6. Conclusion

KBSEAM software is developed which is helpful to solve ergonomic issues of small and medium scale manufacturing industries. This software provides the user-friendly interface which can be assessed by anybody without any software knowledge. The developed software not only provides a basic awareness about ergonomics but also guides the user to access ergonomic tools for their activities. It also contains the ISO standards and guidelines which are helpful for manufacturing industries to follow them as a guideline to minimize the work-related ergonomic issue in their industries. It is one of its kind software which can not only be used to gain knowledge about ergonomics but also can be used to evaluate, assess tasks and provide necessary guidelines. To evaluate its capabilities, an example of the Sawmill is considered. Initially the workplace is studied by learning the fundamentals of ergonomics from module 1 of the KBSEAM software. Later the evaluation of the work is carried out using the module 3 of the software. It contain the various assessment tools from which, the REBA tool is used to assess the MSDs issue in lifting and carrying the wooden logs. This issue is solved by using the standard and guideline module of the software. The guidelines are provided in the software, in which various lifting and transporting devices are mentioned which can be used for lifting the heavy load from one place to another in sawmill. This reduces the strain on the worker's body thereby reducing the MSDs issues among the Sawmill workers.

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Biography

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