

Design and Implementation of a Database for Safety and Ergonomics in Engineering Research Labs

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Abstract

Workplace safety and ergonomic risks exist in almost any work environment. In laboratories, workers are at risk of Musculoskeletal Disorders (MSDs) and other injuries due to repetitive and static motions and adverse environmental conditions. For this reason, safety and ergonomics within laboratories are becoming extremely important to minimize risks for experimenters. This paper proposes a framework for assessing occupational risks in engineering research labs and develops a database system for safety and ergonomics. The database provides lab users with an efficient way for storing and retrieving data. A conceptual model for the database was created using Entity Relationship Diagram (ERD). Data was collected using surveys, manual assessments, lab records, and other sources. Safety data was obtained through an assessment conducted by the Safety Committee and ergonomic data was obtained by an assessment conducted by the research team. The database was implemented in Microsoft Access® and tables were created for lab information, safety and ergonomics, lab equipment, materials, and research activities.

Keywords

Database design and implementation, Entity Relationship Diagram, engineering labs, safety, ergonomics

1. Introduction

Workplace safety and ergonomic risks exist in almost any work environment. Each year, many workers are killed or injured on the job in the United States and other countries. According to the Occupational Safety and Health Association (OSHA), almost 3.1 million nonfatal workplace injuries and illnesses were reported in 2010 among private industry employers in the United States (incident rate: 3.5 cases per 100 equivalent full-time workers).

Workplace safety and ergonomics are two related aspects. Ergonomics, which is the study of the relationship between people and their work environment, is very important for the safety and health of workers in the workplace. The workplace safety, also known as occupational safety, focuses on promoting the safety of the workers to prevent workplace illnesses, accidents, injuries, and fatalities.

Laboratory workers are at risk of Musculoskeletal Disorders (MSDs) and other injuries due to repetitive and static motions and adverse environmental conditions. Routine laboratory procedures such as working with chemicals, microscopes, and operating CNC machines are some factors that promote MSDs and other safety hazards. Repetitive and static motion injuries develop over time and occur when muscles and joints are stressed, tendons are inflamed, nerves are pinched and blood flow is restricted. Environmental conditions such as noise, temperature, and illumination can also affect the health and well-being of workers.

According to OSHA, over 500,000 employees are currently work in laboratories in the United States. Laboratories workers can be exposed to hazardous materials and machines as well as experience many ergonomic risks. For this reason, safety and ergonomics within laboratories are becoming extremely important to minimize risks for experimenters. Laboratory workers and employers should not only be aware of the immediate safety hazards associated with their individual labs but also the task-related risks such poor posture, frequency, vibration, mechanical pressure, and fatigue from force and duration related tasks within their laboratories.

According to Sousa et al. (2015), occupational safety and health has been and still a topic of intense research and practical developments. The focus on the occupational safety and health includes: 1) accident analysis and prevention, and 2) risk assessment and mitigation. Ergonomics is an integrated part of both cases. Ergonomic risk factors cause biomechanical stress on the worker contribute to the risk of developing Musculoskeletal Disorders (MSDs). The first step for developing an effective ergonomics program to eliminate injuries is to understand how ergonomics affect people. Table 2 summarizes the main ergonomic risk factors. These risk factors, either alone or in combination, can subject the workers to MSDs. However, to contribute to MSDs, the ergonomic risk factors must be present for a sufficient duration, frequency, and magnitude. Before designing any workplace or analyzing the ergonomic risk factors for a task, ergonomic requirements need to be identified. Ergonomic requirements are the guidelines and recommendations for designing, constructing, and modifying workstations and work environments to avoid ergonomic risks. Ergonomic requirements are all about preventing strains and other injuries to workers and providing them with a safe environment to work.

In order to perform a continuous and effective assessment of safety and ergonomic risks for the lab environment, all related data and information should be accessible and updated. A database, which is a collection of organized data, can be used for this purpose. A database contains a number of different tables that are related to one another using query. These data can be grouped logically to derive information with greater ease. There are several different ways that a database can be organized. The most prevalent approach is the relational database, a tabular database in which data is defined so that it can be reorganized and accessed in a number of different ways. Relational databases can be used to improve the ability of individual laboratories to efficiently manage their resources. For example, they can be used to provide information about equipment inventory, machine status, lab users, safety risks, etc.

The rest of this paper is organized as follows: Section 2 provides a review of some literature related to safety and ergonomic risks and the development of database systems to track and manage such risks in different environments. Section 3 presents the proposed research methodology for assessing safety and ergonomic risks in engineering research labs and the development of a database system to manage them. Section 4 briefly talks about the implementation of the proposed database in Microsoft Access® software. Finally, Section 5 concludes the paper and highlights some future work areas.

2. Related Literature

Assessment of ergonomic risks and musculoskeletal disorders (MSDs) is an important aspect of workplace safety. MSDs have been a common complain among workplace workers involved in statistic and repetitive motions and awkward postures. Several researchers have conducted studies to assess the ergonomic and MSDs in the workplace. For example, Poochada and Chaiklieng (2015) performed an ergonomic assessment of workers in a call center to identify and prevent the risks of MSDs among the workers. Several MSDs were identified and the authors recommended ergonomic training for the workers and improving the design of the workstations in order to prevent the MSDs. In another study by Kushwaha and Kane (2016), assessment of ergonomic risks and workstation design in steel industry was conducted. The study showed that the intervention of ergonomics in the workplace can minimize the mismatch between man and machine and hence makes the workplace more comfortable for workers. Assessment of ergonomic risks among office workers using Rapid Office Strain Assessment (ROSA) was presented in Matos and Arezes (2015). Fabbro and Santarossa (2016) presented a real time approach for ergonomic analysis in manufacturing process. Safety and ergonomic risks in academic laboratories have also been studied by some researchers. Wargniez *et al.* (2012) presented a case study for improving laboratory safety through mini-scale experiments. The study highlighted the importance of stakeholder involvement, organizational commitment, and environmental projects or promoting safety in chemical laboratories.

Database systems are used in almost every company and organization. The design and implementation of database systems in different industries and for different applications has been discussed by many researchers. A database system for food safety information in Greater China was discussed in Chen et al. (2016). The study introduced methods used for data extraction, processing, and search. Over 1,300,000 pieces of entry have been collected through websites of government agencies, related literature, and news in credible online media. Ying (2014) discussed a database design for pop music website development. The study presented a conceptual model for the database design as well as the database tables with their entries and keys. Sargent et al. (1996) presented a new database model for human genome research. The authors explored two advantages of their proposed approach: representational flexibility and reflective

use of meta-data to accomplish schema evolution by ordinary updates. In a similar study, Brown et al. (2005) designed and implemented a database for image analysis research. A generic process and data models for quantitative image analysis (QIA) in medicine is presented. In addition, data mining for statistical analysis was described with example queries. A spatial database system for seasonal influenza was designed and implemented by Ren et al. (2011). The developed database system provides uniform spatial reference for spatial analysis of seasonal influenza and environmental factors. An object-oriented spatial database of coalfields geological hazards was presented in Bei et al. (2010). Zhang et al. (2016) developed an incident database that is used for quantitative risk assessment and to promote the safety management in Shanghai metro. Erfeng et al. (2008) developed a multi-dimensional database system for dam safety monitoring.

In this paper, we develop a database system for engineering research labs considering safety and ergonomics. The database system provides a reference for the safety committee to access and analyze historical safety assessment data. Lab users and technicians can also use the database to check the current and historical research activities performed in the labs and the maintenance status of the lab equipment.

3. Research Methodology

Shown in Figure 1, the proposed framework for developing the lab database focuses on identifying and collecting lab data and implementing the database in MS Access. The framework starts with developing a conceptual model for the database. Then all the labs of interest as well as the coordinators and users of each lab are identified. The next step is to collect data, either manually or from existing resources, for the tools, equipment, and materials used in each lab. The jobs and research activities performed in each lab are also identified. Safety and assessments is performed for all the labs and the results are stored in dedicated tables in the database.

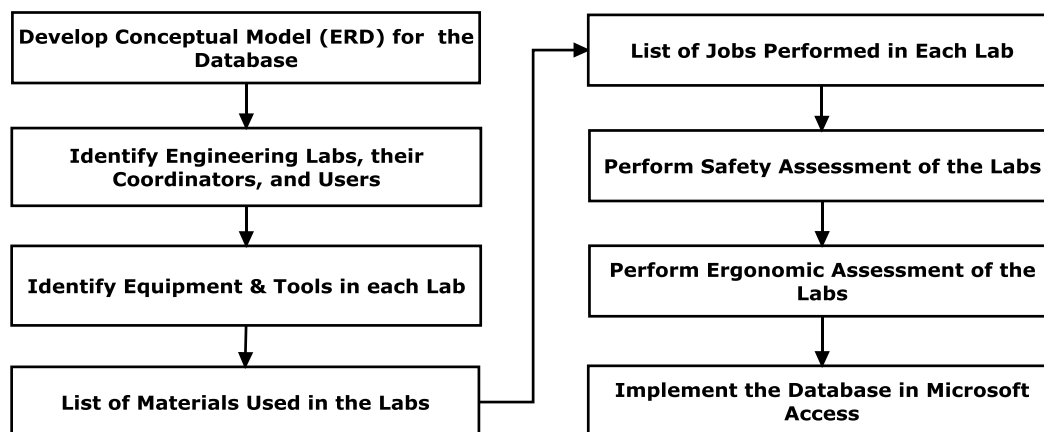


Figure 1. Proposed framework for lab database

The Entity Relationship Diagram (ERD) for the engineering lab database is shown in Figure 2. The database consists of six main tables: safety table, ergonomic table, lab information table, lab equipment table, lab units table, and research activity table. The safety table includes all the safety related data such as safety issues, resolutions, and project. Ergonomic table include ergonomic related data and information such as ergonomic risks, assessment date, and ergonomic status (e.g., Green, Yellow, Red). The lab equipment table stores the equipment data including maintenance and repair data and ownership and location information. The other tables include data about labs, lab users, and research activities.

For ergonomic assessment, Ergonomic Heat Map (EHM) was developed as a way to visualize ergonomic risks on the different parts of the human body. The human body is divided into 24 parts in addition to the eyes, mouth, and ears. An illustration of EHM is shown in Figure 3. Noise is illustrated by the ears, illumination is illustrated by the eyes, and the posture and force risk factors are represented by the other parts of the human body. The mouth shape (or color) is an indicator of worker's feedback regarding the workplace ergonomic conditions and is also used to validate the ergonomic evaluation of the workplace. Four color codes are used: green for low or no risk, yellow for medium risk, brown for high risk, and red for very high risk. Each part of the body is evaluated to identify the ergonomic risk of the workplace. A sample of the ergonomic assessment survey used in EHM is shown in Figure 4.



Figure 2. Entity Relationship Diagram (ERD) for the engineering lab database

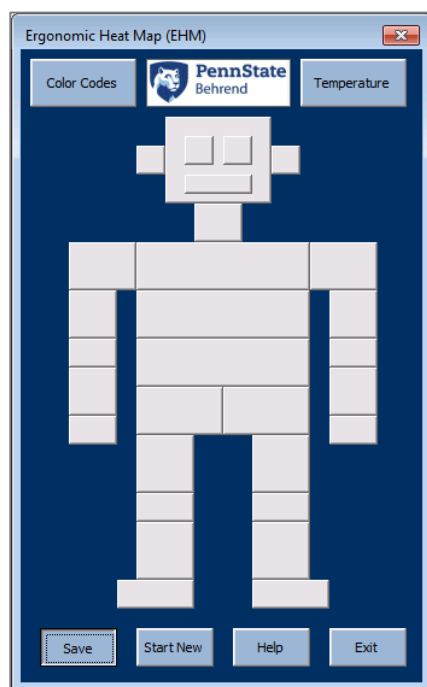


Figure 3. Ergonomic Heat Map application

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

A1 Almost neutral?

A2 Moderately flexed or twisted or side bent?

A3 Excessively flexed or twisted or side bent?

B Select **ONLY ONE** of the two following task options:

For seated or standing stationary tasks. Does the back remain in a **static** position most of the time?

B1 No

B2 Yes

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the **movement** of the back

B3 Infrequent (around 3 times per minute or less)?

B4 Frequent (around 8 times per minute)?

B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

C1 At or below waist height?

C2 At about chest height?

C3 At or above shoulder height?

D Is the shoulder/arm movement

D1 Infrequent (some intermittent movement)?

D2 Frequent (regular movement with some pauses)?

D3 Very frequent (almost continuous movement)?

Figure 4. A sample of Ergonomic Assessment Survey

4. Database Implementation and Lab Assessment

The database was implemented in Microsoft Access. The tables were linked using primary keys such as lab IDs, equipment IDs, etc. Figure 5 shows snapshots from the database. The figure to the left is the main interface of the database. The button “Ergonomic Evaluation” is linked to the ergonomic assessment table that includes the ergonomic data for the all the labs. Similarly, the “Safety Information” button is linked to the safety assessment table that includes the safety data for all the labs. The other buttons shown in the main menu include information related to the labs and the research activities and equipment in the labs. The figure to the right shows the lab equipment form which is used to manipulate equipment data. The database is used by the Safety Committee to ensure that lab information and safety assessment is up-to-date. The database is updated using the forms created for equipment, safety, and ergonomic tables. The ergonomic assessment of the lab is performed using the EHM tool created for this purpose. Figure 6 shows the ergonomic assessment results for lab 117. The assessment indicates that the ergonomic risks are in an acceptable level.

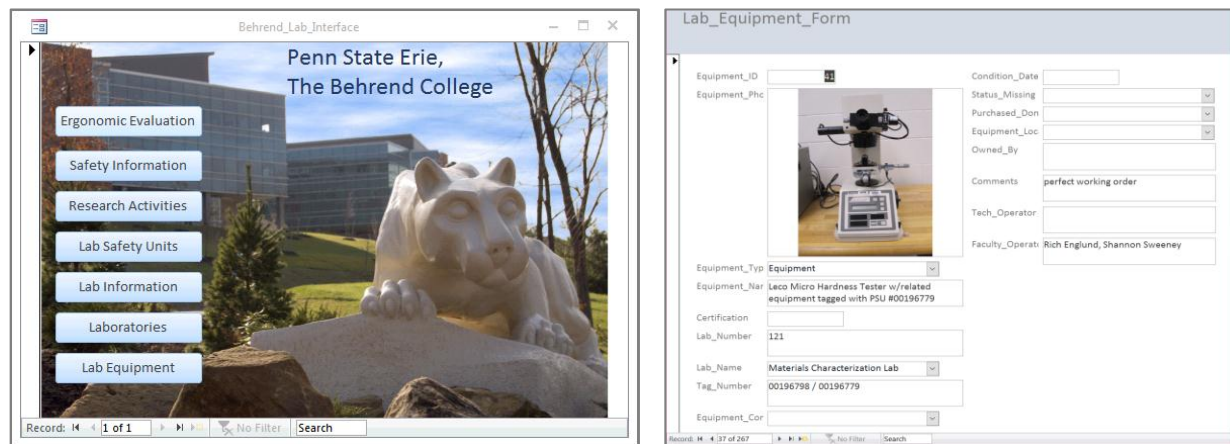


Figure 5. Snapshots from the database

Main Risk Factor	Sub Factors	Measured Value	Unit	Risk Score
Noise (Max)	Noise	82.30	dB	Low
Illumination (Min)	Illumination	38.00	Foot-candle	Low
Temperature (Avg)	Temperature	71.55	F	Low
Humidity (Avg)	Humidity	16.34	%	Medium
Posture, Frequency, and Force (QEC Total Scores)	Back	19.00	-	Low
	Shoulder/Arm	21.00	-	Medium
	Wrist/Hand	18.00	-	Low
	Neck	8.00	-	Low
	Hip	7.10	-	Low
	Knee	8.70	-	Low
	Foot	9.20	-	Low
	Sitting	1.00	-	Low
	Vibration	1.00	-	Low
	Work Pace	2.50	-	Low
	Stress	6.50	-	Low

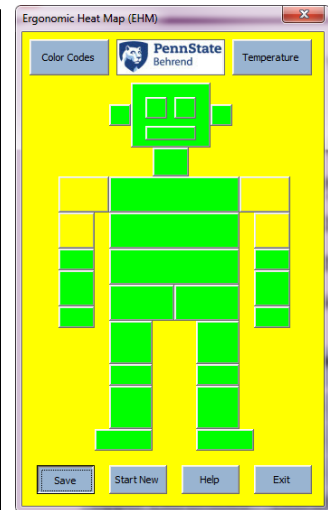


Figure 6. Ergonomic assessment results for lab 117

5. Conclusion and Future Work

Analysis and prevention of safety and ergonomic risks in engineering research labs require continuous assessment in order to prevent injuries and musculoskeletal disorders. Most engineering research labs at Behrend have low safety ergonomics risks. However, continuous assessment is required to identify and mitigate any potential risks that may arise. Developing a database for the labs helps in managing labs data and storing safety, ergonomics, and other information for future use. One limitation of the database developed in this research is that it is based on MS Access, which is not suitable for large databases. As a future work, the Access database created in this paper will be moved to a central database hosted on university server and a web-based interface will be created. This will provide real-time access to multiple lab uses and allows for updating the lab data by the lab coordinators.

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Biography

Faisal Aqlan is an Assistant Professor of Industrial Engineering at Penn State Behrend, Pennsylvania, USA. He earned B.S. and M.S., both in Industrial Engineering, from Jordan University of Science and Technology, Jordan, and Ph.D. in Industrial and Systems Engineering from the State University of New York at Binghamton, New York, USA. Before joining Penn State Behrend, Dr. Aqlan was a faculty member in industrial and system engineering at the University of New Haven where he taught undergraduate and graduate courses. Dr. Aqlan has also worked on different industry projects with Innovation Associates Company and IBM Corporation. His work has resulted in both business value and intellectual property. He holds 7 patents and has published more than 40 papers in reputed journals and conferences. His research interests include logistics and supply chain, system simulation, process improvement, and ergonomics. Dr. Aqlan is an IBM certified for Lean manufacturing and has received numerous awards including the IBM Vice President award for innovation excellence. He is a senior member of IISE and a professional member of IEOM. Currently, he serves as the President-Elect of IISE Logistics and Supply Chain division and a Director of IISE Young Professionals Division. He also served as the chair for Logistics and Supply Chain track in the 2015 and 2016 IISE Annual Conference and Expo, and the chair for Supply Chain track in the 2016 Detroit IEOM conference.