THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF INDUSTRIAL ENGINEERING

DEVELOPMENT AND APPLICATION OF ERGONOMICS IN CHINA

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SPRING 2016

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Industrial Engineering
with honors in Industrial Engineering

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ABSTRACT

In China, as the economy starts to take off, people start to pay more attention to their working environment. People have a lot more choices to choose from, based on their personal preferences. Thus, companies and academia start to pay more attention to the development of China. However, since for each society, people value things differently based on their cultural backgrounds, the definition, development, and application of ergonomics are different from the western world.

In this paper, history of ergonomics is introduced. The definition of ergonomics in China is also synthesized based on the literature review. In China, ergonomics is being applied mostly to the organization management and human resources that focus on human needs. Different methodologies, DEMATEL Model and ISM Model are discussed as well. There is also a case study in a manufacturing workshop in Shanxi, which is one of the first ones to apply ergonomics in its management methodologies. Different elements forming the system in the workshop are discussed and categorized as human factors, machining, and environment. By gathering information from ten management officers and ergonomics experts, elements are evaluated, so that the manufacturer will know where to improve or achieve the best results.

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Chapter 1

Project Background

Nowadays, as the world economy becoming more internationalized, modern enterprises play very important roles in the international economic competition. Modern enterprises start to move away from purely chasing after high growth and economical profits and start to pay more attention to human factors in their own companies. People are the most important element in the company; the growth of the company depends on the development of its people in it. In western countries, ergonomics is commonly used as a scientific tool in enterprise management. Ergonomics has become one of crucial principles applied to the company. Companies start to focus more on the development of human factors: designing the work better, training workers, developing guideline principles, motivating workers, and providing employees a better platform for their own personal and professional development (Sun, 2001).

In China, the high growth of the economy caused many social problems due to the coordination of economic development, cultural factors, resources, and environment. As the Chinese economy started booming, people's life style has been changing drastically. People start to pay more attention to human rights (Qi, 2007). Over years of development, researchers have developed their own methodologies to accommodate company needs in China. However, since the introduction of ergonomics merely 60 years ago, there is still a lot of research needed to be done properly (Xiaoyan & Li, 2007). Only a few enterprises in China realize the importance of human factors, many people are still working under hazardous conditions that would cause potential injuries and negatively affect the production efficiency.

In this thesis, the history and development of ergonomics in China is discussed, as well as the scope of ergonomics. Differences between the western world and Chinese society can be discovered through these sections. One of the most commonly used methodologies is applied to the case study conducted in a manufacturing workshop for a truck manufacturer in Shanxi, in order to give a glimpse of the application of ergonomics in China.

Chapter 2

History of Ergonomics

2.1 History of Ergonomics in the western world

Ergonomics was first formed as a discipline in the late 19th and early 20th century in Britain, but the most fundamental work was accomplished in the United States. Ergonomics is an independent discipline that has more than 60 years history, which can be roughly divided into three stages: the Ergonomics in Industrial Societies, Ergonomics in the Military, and Ergonomics in Information Age.

Since Ergonomics first emerged in late 19th and early 20th century, its development was inevitably intertwined with the development of technology. In the early 20th century, Frederick Winslow Taylor suggested an operational method based on the traditional management methods to improve the industrial efficiency, taken the machine, the person operating the machine, and the working environment as a whole cycle (Meister, 1999). This holistic view of the operation was called the scientific management method, and it laid the foundation for human factors research methods. After the formation of scientific management methods to the start of the World War II, this the stage of development of ergonomics encompassed a variety of needs from the industrial society. The testing method was designed to assist with the selection of workers. Companies applied ergonomics to assign workers to specific positions, develop training programs for workers to maximize their motivation during the operation. Ergonomics was utilized to create the best working conditions for workers in the industry, as well as finding the most effective organizational structure. At this stage, scholars in ergonomics were mostly psychologists, Hugo Münsterberg, a Harvard psychologist, brought up the importance of the psychology on stimulating workers' motivations to improve their working efficiency. These psychologists applied scientific methods. All different requirements from industrial societies, such as selection of workers, training workers, improving working conditions and combating fatigue and so on, had been widely studied and satisfied. Ergonomics had been recognized as a valid way to reduce the operational cost in the industry, while improving the working efficiency for cooperates (Cai, Yu, & Zhuang, 2005).

During the World War II, more complex research and applications of ergonomics were conducted in the military field. The first private effort that focused on ergonomics was established under the commander from the United States Army Air Forces. Britain was also engaged in the research in ergonomics after the World War II (Wu, 2007). Ergonomics started to become an independent subject (Liao, 2006). In 1949, The Ergonomics Society was founded in the UK. The very first textbook on Ergonomics "Applied Experimental Psychology: Human Factors in Engineering Design" was published by Alphonse Chapanis. In 1957, the Human Factors and Ergonomics Society was founded in the United States. In the same year, the first edition of the journal Ergonomics was published, which became the most honored international publication forum in the academia (Liao, 2006).

In the 1960s, Ergonomics was booming with the emergence of the Information Age. New theories, such as Cybernetics and User Interface began to play a greater role in the ergonomics discipline. Man, machine, and environment are all taken into consideration and are integrated into an inseparable cycle, so that the most desirable operating circumstances could be accomplished, as well as accomplishing the efficiency. At this stage, the application of ergonomics is human centric and focus on the design of the machine. The operation will be designed to meet human needs and never exceed human's capacity. The product design is often interdisciplinary to find the most optimal solution for the need of the user (Cai, Yu, & Zhuang, 2005).

2.2 History of Ergonomics in China

Ergonomics was first known and studied in China in the early 1950s. In the 1960s, study were majorly conducted in the infrastructure construction field. Ergonomic was applied to the design of the railway center display signal station, the standardization of the lighting system in the building, and the calibration of the scale in the industry and so on. From 1966, Ergonomics had begun to be widely applied in the industrial society, such as in the steel manufacturing and textile manufacturing, and it was used to develop a better operating method and more effective training method. Ergonomics was even applied to the pilot selection, training, and combating pilot error, etc. in the military field (Gan & Sun, 2005).

In the late 1970s, to better assist with the modernization of the national defense and manufacturing industries, related research was vigorously advocated by the government under the name of "human factors engineering" (Ding, 2004). In 1989, the first national academic organization, Chinese Ergonomics Society (CES) was established. The establishment of the Chinese Ergonomics Society is one of the milestones in the history of ergonomics development in China. Chinese Ergonomics Society is now a member of the International Ergonomics

Association. As the development of ergonomics in China, in-depth engineering studies of people, people gradually realized the importance of the subject on national economic development. At present, the subject of research and applications has been extended to industry, agriculture, transportation, health care, education system and other sectors of the national economy, promote the penetration of the cross-disciplinary engineering and technology and related subjects, making it an interdisciplinary subject (Xiaoyan & Li, 2007).

Chapter 3

Definition of Ergonomics

3.1 Definition of Ergonomics in the western world

Ergonomics is designed in accordance with the characteristics of human, machine, and the environment to form a holistic system (H & T., 2005). This system is an integration of the person, the machine operated by the person, and the environment that they presented. In order to achieve the best match man, machine and the environment, ergonomics focus on optimization as its main object, intended to enable people in different environments work safely, healthily, comfortably and efficiently during their work and even in their lives (L.Cullen, 2007).

Ergonomics have evolved with many definitions at different phases.

In ancient industrial societies, represented by Frederick Winslow Taylor, the science of ergonomics was a management method, in which human was like a part of the machining system that needed to achieve its optimal efficiency at minimum cost. Later on, as well beings of workers being taken more seriously and rigorously, scientists and engineers in ergonomics started to pay more attention to benefits of workers. Vladimir Bekhterev and Vladimir Nikolayevich Myasishchev argued that the work design in the industry should focus on not only achieving maximum efficiency, but also minimum health hazards, as well as preventing potential fatigue from work. In the Information Age, ergonomics has developed a branch subject in the field of human-computer interface that focus on satisfying human needs, using advanced technologies in human sciences, such anatomy, psychology, and human kinetics.

3.2 Definition of Ergonomics in China

In 1979, Ergonomics was defined in “Ci Hai”, the most authoritative dictionary, as “human factors engineering”. It is referred to as an emerging interdisciplinary, in which anthropometry, physiology, psychology science, biomechanics, and engineering disciplines are utilized as scientific tools to conduct research study. Ergonomics is a comprehensive study of human structure, function, and psychological problems, as well as mechanical problems (Wang, Liu, Pu, & Yu, 2010).

Chinese Ergonomics Society, referred to as CES, defined ergonomics as a study of various factors, including anatomy, physiology and psychology, in certain working environments. Ergonomics is research on how people, machine, and the working condition interacting with each other, and it is also a study on how to plan and coordinate the human health, safety, usability, and productivity issues (Liu, Qi, & Yang).

These definitions of ergonomics are based on the development of ergonomics in the Chinese society over the past decades. They can be integrated into one broad definition of ergonomics as a study of the relationship between human, machine, environment among the three, in order to achieve better work, study and life style, in a safer and friendlier way that encompasses physiology, anthropometry, engineering and management disciplines (Ye & Cai, 2009).

Chapter 4

Development of Ergonomics in China

4.1 Scope of Ergonomics

Ergonomics encompasses almost every aspect of human activities, which includes following main studying fields:

- Work design to promote efficiency under different operating conditions (Niu, 2003);
- Ensuring a safe and comfortable working environment for workers from psychological and physiological perspectives;
- Work design and training procedure in the automated industry, in which the work distribution between the machine and the operator needs to be considered. Based on human physiological and psychological characteristics, coordination of the machine operating system can be designed. Training methods can be developed by studying how the operator interacts with the machine. The operator's reaction time, movement speed, and range of movement need to be taken into consideration, in order to precisely identify the workload, energy consumption, fatigue factors that influence the worker's reliability (Wang Y. , 2003);
- Developing a variety of products that can apply ergonomics techniques, including machinery, vehicles, public service facilities, and even household appliances (Wang, Wei, & Jiang, 2008).

4.2 Focused area in Ergonomics

A research has been done on studying a variety of journals in ergonomics, including Chinese Journal of Ergonomics, Industrial Engineering Journal, Industrial Engineering and Management, Science Research Management, Systems Engineering, China Occupational

Medicine, Journal of University of South China, Measurement and Control Technology, Shanxi Science & Technology of Communications, and China Railway Science, etc. By studying key words in publications from January 2001 to March 2005, different publications in ergonomics were categorized into eleven different directions: Product Design and Evaluation, Human Errors and Safety, Workload and Fatigue, Work Design and Working Environment Improvement, Cognitive Ergonomics, Working Environment Examination, Occupational Needs Study, Ergonomics in the Cutting Edge Technology, Organizational Ergonomics in Management, Physical Ergonomics, and Human-Machine System Study (Guo, Sun, & Ye, 2007). The percentage of publications in each direction is shown in Figure 1.

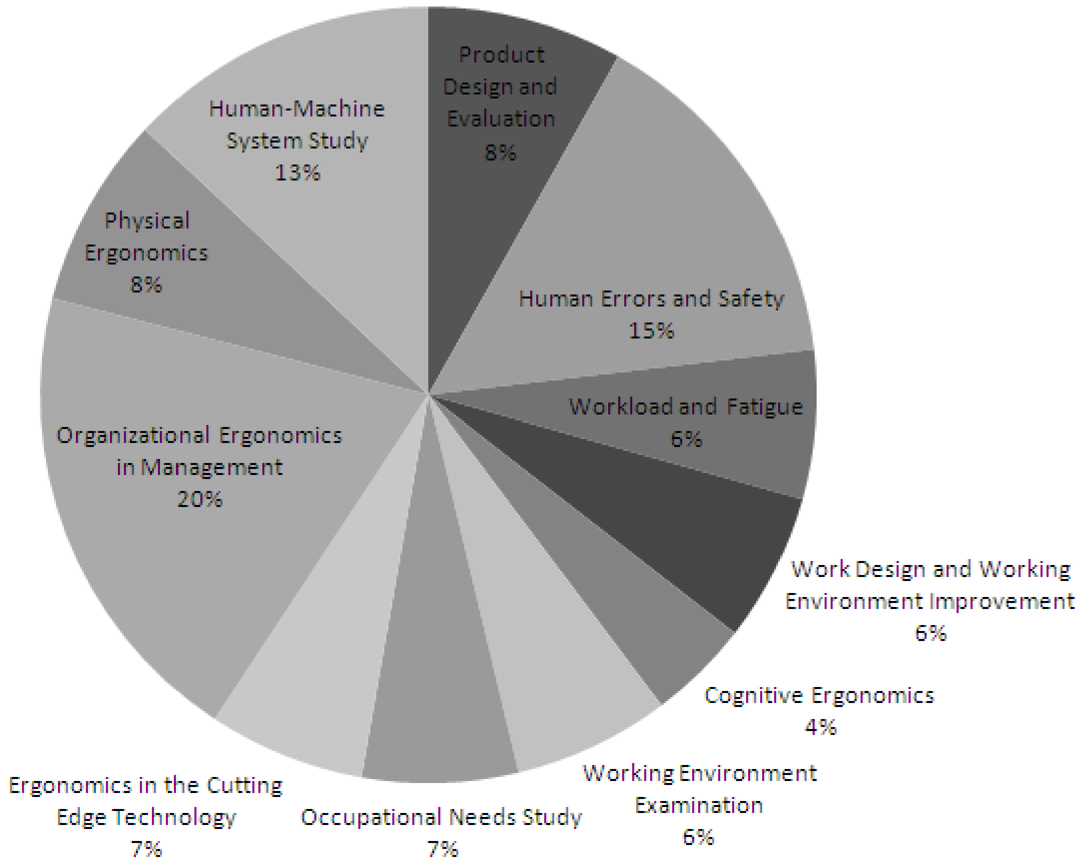

Figure 1 The percentage of different research directions in Ergonomics in China (Guo, Sun, & Ye, 2007)

It is found that in these years, majority of publications is still focus on utilizing ergonomics in organization management, which shows that ergonomics is more often being applied to the human resource management field. Human Errors and Safety is the second subject being studied the most has shown that ergonomics is applied to study and improve working safety in China, especially in the manufacturing and traffic management field. The number of publications in Occupational Needs Study and Working Environment Examination is close to each other, which shows that researchers and practitioners pay equally attention to the human needs and how to set up the working environment to achieve the maximum efficiency possible.

The number of studies in Product Design and Evaluation, Workload and Fatigue, and Work Design and Working Environment Improvement is relatively small, which shows that ergonomics has not yet been applied widely in such fields. Cognitive Ergonomics and Ergonomics in the Cutting Edge Technology are relatively new topics in the world, and even though they have not been widely studied, but they have huge potential to change the whole field in the Information Age (Guo & Yang, Human Factors).

In conclusion, ergonomics is being applied mostly to the organization management and human resources that focus on human needs. Thus, methodologies being applied in ergonomics field are to better serve the purpose to achieve maximum efficiency possible, as well as to create a comfortable environment for people to work. These methodologies are going to be discussed in the following chapter.

Chapter 5

Methodology of Ergonomics

There are many different models can be used to analyze complex system that involves human factors. In this Chapter, two methodologies will be discussed, the Interpretive Structural Modeling and the Decision Making Trial and Evaluation Laboratory Modeling. Both modeling methodologies are commonly used in the ergonomics academy in China (Yang, 2001).

5.1 ISM Model

Interpretive Structural Modeling (ISM) is the most commonly used methodology to study complex issues that contain human factors. ISM breaks down the complex system into small subsystems, and by using expert experiences, knowledge, and computer modeling will be applied to construct a hierarchical structure that represents the system. The ISM Model is widely applied in all different fields, from energy crisis analysis to personal problems. ISM seizes the root problem of the system to find the most effective solution and benefit the majority of stakeholders involved (Ren & Yu, 2004).

When applying the ISM method, the system being studied needs to be defined; elements that form the whole system need to be identified; and relationships among elements need to be calcified. The structure of the system will need to be visualized and presented for further discussion (Ruan, 2008).

Detailed steps to apply such model are as followings (Zhang & Xie, 2002):

First of all, a group of experts from different backgrounds need to be gathered together to ensure accountability of the decision making process. If possible, people with different opinions towards the topic need to be included in the group, so that the problem can be viewed objectively. The number of people in the ISM group should be around ten people to facilitate the discussion effectively.

The problem is defined within the group, and group members need to be prepared and present their opinions toward the issue on paper, so that different opinions can be fathered efficiently.

Elements that form the system are identified and validated by group members, based on their experiences and expertise. All group members write down issues and problems related to the system being studied, and these information will be gathered and summarized by one person. The whole section requires all group members to be capable of discussing and researching for the system at the same time. At the end of the discussion, a structure will be constructed with all possible elements involved in the system represented.

The Reachability Matrix R, a binary matrix, will be created that represents the relationships between each element. If there is a direct or indirect relationship from element T_i to element T_j, the reachability matrix of R_{ij} is 1; otherwise, R_{ij} equals to 0.

The Reachability Matrix will then be decomposed to structural models, that based on algorithms. The interpretive structural model can then be created by using interrelationships among all elements.

5.2 DEMATEL Model

Decision Making Trial and Evaluation Laboratory (DEMATEL) Model is a structural analytical model, in order to help solve the world’s most complicated and difficult challenges. It was developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976 (Zhou, 2005). DEMATEL is a method of utilizing graphic and matrix as tools for the problem analysis. The problem is broken down into different influence factors. Through listing logical relationships between each influence factor and directly visualizing such relationships in matrices, the level of each factor’s influence on other factors and the whole system can be found. In this way, the degree of each factor’s degree of centrality can be calculated to reveal the structure of the system and reasons behind the structure.

The DEMATEL Model is commonly seen to be applied to evaluate enterprise’s innovation capability, evaluating urban planning, and military field. It is recognized by the academia as the one of the most effective models in study most complex problems in the world. Moreover, the DEMATEL Model can be applied to the ergonomics field (Zhang, Zhou, & Tang, 2009).

When applying DEMATEL Model, information from all different aspects of the system being studied needs to be gathered as objectively as possible. Detailed steps to apply such model are as followings:

First of all, elements that form the system need to be identified and validated, and for a system that contains a total number of n elements, each element will be labeled as T_1, T_2,
T_3, ……, T_n.

The direct impact between each individual element needs to be determined, and the level of impact should also be represented. If the element T_i has direct impact on element T_j, then there should be an arrow pointing from T_i to T_j. The level of impact will be represented as numbers labeled above the arrow, showing the strength of the impact. The "strong impact”, “medium impact", “weak impact", and "no impact” will be represented as 3, 2, 1, 0 respectively. The direction of the arrow marked the direction of the direct impact of between two elements.

A matrix that represent the direction and level of the direct impact on each element. In the matrix, aij will be the number labeled on top of the arrow pointing from element T_i to T_j, and if there is no arrow from element T_i to T_j, aij=0. For the number of n elements, there will be a n×n matrix.

In order to standardize the direct impact matrix to matrix G, a formula shown below in Formula 1 needs to be used.

$$G = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}$$

(1)

By calculating G^2, the level of indirect impact from element T_i to T_j can be obtained. The synthesized impact matrix can be calculated using the Formula 2, in which s_i represents the impact factor of each element. The level of direct and indirect impact of element T_i on element T_j will be represented as s_{ij}.

$$S = X(I - X)^{-1} = s_{ij}$$

(2)

The sum of each row from the synthesized impact matrix is the impact of each factor s_i, which is represented as f_i, can be obtained using the Formula 3.

$$f_i = \sum_{j=1}^{n} s_{ij} \ \ (i = 1,2, \dots, n)$$

(3)

The sum of each column from the synthesized impact matrix is the impact on each factor s_i from other elements, which is represented as e_i, can be obtained using the Formula 4.

$$e_i = \sum_{j=1}^{n} s_{ji} \ \ (i = 1,2, \dots, n)$$

(4)

Centrality x_i refers to the importance of each factor s_i. Each factor's centrality x_i can be obtained by summing up both e_i and f_i, using the equation shown below in Formula 5.

$$x_i = f_i + e_i \tag{5}$$

In order to tell if the factor is the reason of causes or result of causes, the difference between e_i and f_i needs to be calculated, using the Formula 6.

$$y_i = f_i - e_i \tag{6}$$

If $y_i > 0$, then factor s_i will be considered as a reason factor; otherwise, if $y_i < 0$, then factor s_i will be considered as a result factor, which means that it is a factor being influenced.

Often the centrality and reason factors are utilized to simplify the whole system and give advises to improve the system's performance.

Chapter 6

Case Study

In this case study, a manufacturing factory in Shanxi was studied. The company was founded in 2004. It is a truck factory that consists of R&D, production, assembly, sales, and after-sale service. The manufacturing factory possesses total assets of 1 billion, with 100,000 square meters construction areas. It deploys the most advanced production lines, including stamping lines, welding lines, painting lines, and assembly lines. The factory is also highly automated compared to most of assembly lines in China. It has 2,000 employees working in the factory, in which 40 percent of employees received college education. This factory's education level is considered to be high among other factories in China. Most of the research done in this case study was in its production workshop.

In following sections, human factors, machining, and the environment of the production workshop will be discussed and evaluated through DEMATEL Model.

6.1 Human Factors

Human factors can be viewed from three different perspectives, physical, physiological, and psychological perspective.

Physical human factors refer to the physical appearance of employees working in the workshop. The form of human body defines the labor work that individuals can achieve. When the manufacturing factory needs to design and to purchase machines and tools to be added to the workshop, they need to consider if workers are physically capable of using these equipment. By measuring different human body parts, such as the head, neck, trunk, upper limbs, and lower limbs, they can better determine the size of the tool or the machine.

Physiological human factors refer to the physiological characteristics of human body show during the process of interacting with the outside environment. This process often contains energy consumption, oxygen demand, cardiac output, blood pressure, and fatigue, etc. These factors need to be carefully studied by using references from academic research and annual body examination reports of workers. These factors are used to better design the working schedule and to determine the maximum workload during each shift.

Psychological human factors refer to psychological activities during the working procedure. Feelings are the simplest psychological process, and they help workers to familiarize their working process, improve their working skills, and give them ability to distinguish the outside world. Perception refers to the process of forming one's own understanding from a more holistic view. The more knowledge the worker has access to, the more objective their perception will be, regarding to the manufacturing procedure. Memory is another important psychological activity that helps workers familiarize themselves with the manufacturing process. Personality is considered as an important human factor that is often missed. It is important for the management level to recognize each individual's personality to better motivate his or her daily work.

6.2 Machining

The workshop being studied mainly consists of two major machines that people are interacting with, monitors for displays and controls. Display devices are utilized to display information for operators to run the machine safely. Controls are utilized to allow operators to interact with machines and give command to machines.

There are three types of display devices for the factory to choose from, visual display, auditory display, and tactile display. It is important to study how operators receive, recognize, accept, and process the information being displayed through these monitor devices. Thus, monitor devices can be calibrated, so that operators can accurately respond to the information promptly.

In this workshop, there is a visual display monitor, which is a digital display device. This digital display device is easy to read and intuitive. It is used to directly reflect the operation status of machines, such as showing the temperature on the boiler, the indoor humidity to prevent potential corrosion caused by moisture, and the pressure inside the machine, etc. This display device needs to accurately show the predetermined criteria, easy to be understood by employees, and not exceed physiological limits.

Auditory display device has the advantage of not affecting by lighting conditions. In this workshop, the welder operator is asked to wear an auditory display device to alert the person when the body part is exposed to the arc or touches the welding clamp during the welding process. During the welding procedure, it is highly likely that the welder operator cannot spot potential dangers on time, using the auditory display device can prevent potential pain or damage to human body.

Tactile display consists of feelings caused by textile, pressure, pain, vibration, and shape. These feelings convey a sense of body movement, so that people could quickly respond when uncommon things occurs. In this production plant, the automated machine needs to be initiated by a touch screen, and the worker can interact with the machine through the touch screen, monitoring the machine's operation. The vibration from the touch screen could effectively alert the operator, if there is any error operation command.

In the workshop being studied, there are three ways to differentiate controls for different uses.

Different colors are used to distinguish different operation status. Red buttons are frequently used as a stop button that could shut down the facility when emergency occurs. Words and numbers are used to guide the operator through the right operation orders and distinguish different machines. The size of controls is also an intuitive way to show operators which controls are more important than the other ones.

6.3 Environment

In this manufacturing factory's workshop, it is crucial to eliminate as many unsafety factors as possible, not only to ensure the safety of operators, but also to achieve the optimum manufacturing capacity of the factory. However, it is unrealistic to fully have the environment under control, due to the technology and budget limits. Thus, in this case study, five most important aspects of the working environment are taken into consideration, the temperature, lighting system, noise, vibration, and microclimate.

In this workshop, it is important to be aware of the importance of the temperature, because there is a welding procedure included in it. If the temperature is too high, the welder operator won't be able to release the amount of heat generated, which may cause the body temperature to rise. If the body temperature gets too high, the person may feel dizzy, lose consciousness, and even die from it. The temperature inside the workshop should not be too low for employees outside the welding workshop, because it may cause them making more mistakes and work less efficiently. The factory controls the temperature in the workshop to be around 27 ˚C, and the standard deviation should be limited to 3 ˚C. In the welding workshop, it is better to shorten the time of each shift, provide with enough drinking water to prevent dehydration, and provide medical support to the workshop when necessary.

The lighting system of the manufacturing workshop consists of the natural light and artificial lights. A well-designed lighting system could prevent employee's mistakes and fatigue to improve the productivity of the factory. It is also important to reduce employees' stress from work through lighting system. Walls of the workshop are painted to white to reflect as much light back to the room as possible to make it bright, so that people inside the room can feel lighter emotionally.

Noises often occur in the workshop, because the manufacturing process involves with many machining processes. Sources of such noises are mainly from the gas release from the stamping process; friction, rotation, and vibration from welding process and moving parts; sounds made by operators during the manual processing procedure. Noises could easily distract employees and cause many mistakes and injuries, if not under control. It is known that the noise level drastically decreases with the distance from the source of the noise increases. Thus, offices in which more intellectual work proceeds are kept away from noise sources. The workshop also utilizes noise reduction materials on their walls to reduce the sound transmission. For employees that have to work in noisy environment, they are required to wear ear buds that cover the whole ear to prevent potential damage from the noise.

In this workshop, there are some manual works that need to be done with hammers. To prevent damage from the vibration during the usage of tools, every hand tool uses soft materials that have damping characteristics. Workers are also require to wear gloves during their work.

Microclimate consists of the temperature, humidity, airflow, and radiation inside the workshop. The microclimate will not directly cause damage to human body, but has huge effect on psychological activities. Thus, it is important to take control of these microclimates, so that people in the workshop can work comfortably.

6.4 DEMATEL Analysis

In the previous three sections, ergonomics elements, human factors, machining, and environment, in the workshop in the manufacturing production plant were discussed in details. Based on all information gathered, these elements can be organized as shown in Figure. These elements are being used in the following DEMATEL analysis.

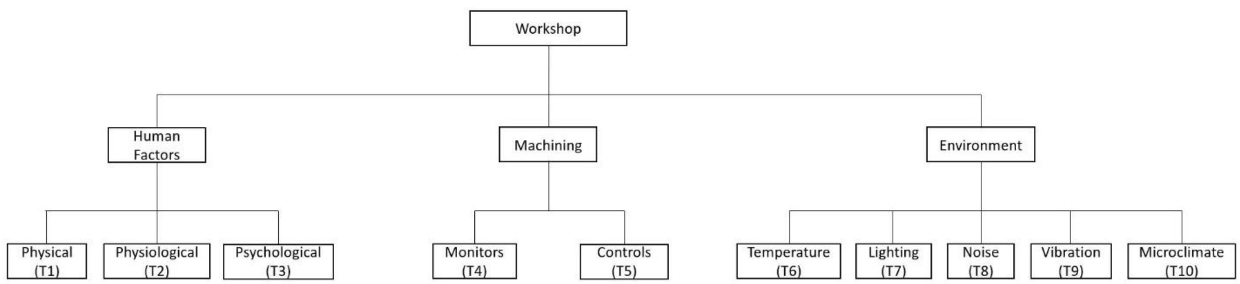

Figure 2 Ergonomics Elements in the Workshop in Shanxi

Ten experts in either ergonomics field in China or the management level of the manufacturing factory were asked to rank the influential factor for each element from 0 to 3. For an element with a value of zero, it means that there is no relationship between two factors. The influential factors gathered from these ten people are shown in Table 1.

Table 1 Influential Factors of each Element

Elements / **Expert**	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*T7*	*T8*	*T9*	*T10*
E1	0	2	3	0	0	0	0	0	0	0

E2	1	0	2	0	0	0	0	0	0	0
E3	3	2	0	0	0	0	0	0	0	0
E4	2	1	1	0	1	2	1	1	0	1
E5	1	1	1	3	0	1	0	3	1	1
E6	1	2	2	1	1	0	0	0	0	2
E7	1	0	2	1	1	1	0	0	0	2
E8	1	1	3	1	0	0	0	0	0	0
E9	1	1	3	2	2	0	0	0	0	0
E10	1	2	2	1	1	2	0	0	0	0

By applying DEMATEL Model, the direct impact matrix X^d can be written into the formula shown below.

$$X^d = \begin{bmatrix} 0 & 2 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 3 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 2 & 1 & 1 & 0 & 1 & 2 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 3 & 0 & 1 & 0 & 3 & 1 & 1 \\ 1 & 2 & 2 & 1 & 1 & 0 & 0 & 0 & 0 & 2 \\ 1 & 0 & 2 & 1 & 1 & 1 & 0 & 0 & 0 & 2 \\ 1 & 1 & 3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 3 & 2 & 2 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 2 & 1 & 1 & 2 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{7}$$

Using the formula $G = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}$ to change the matrix into the formula shown in Formula 8.

$$X_1 = \begin{bmatrix} 0 & 0.1667 & 0.25 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0833 & 0 & 0.1667 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.25 & 0.1667 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.1667 & 0.0833 & 0.0833 & 0 & 0.0833 & 0.1667 & 0.0833 & 0.0833 & 0 & 0.0833 \\ 0.0833 & 0.0833 & 0.0833 & 0.25 & 0 & 0.0833 & 0 & 0.25 & 0.0833 & 0.0833 \\ 0.0833 & 0.1667 & 0.1667 & 0.0833 & 0.0833 & 0 & 0 & 0 & 0 & 0.1667 \\ 0.0833 & 0 & 0.1667 & 0.0833 & 0.0833 & 0.0833 & 0 & 0 & 0 & 0.1667 \\ 0.0833 & 0.0833 & 0.25 & 0.0833 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0833 & 0.0833 & 0.25 & 0.1667 & 0.1667 & 0 & 0 & 0 & 0 & 0 \\ 0.0833 & 0.1667 & 0.1667 & 0.0833 & 0.0833 & 0.1667 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{8}$$

Using the formula$S = X(I - X)^{-1} = s_{ij}$ to obtain s_{ij} to obtain the synthesized impact matrix, shown below in Formula 9.

$$X_2 = \begin{bmatrix} 0.098 & 0.2353 & 0.3137 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.1411 & 0.0588 & 0.2118 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.298 & 0.2353 & 0.1137 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.3537 & 0.2928 & 0.3501 & 0.0839 & 0.1312 & 0.2248 & 0.0903 & 0.1231 & 0.0109 & 0.1537 \\ 0.3371 & 0.3283 & 0.4114 & 0.3369 & 0.0723 & 0.173 & 0.0281 & 0.2961 & 0.0893 & 0.1509 \\ 0.2667 & 0.3445 & 0.3727 & 0.1420 & 0.1203 & 0.0683 & 0.0118 & 0.0419 & 0.01 & 0.2019 \\ 0.2654 & 0.1967 & 0.3684 & 0.1539 & 0.1303 & 0.1573 & 0.0128 & 0.0454 & 0.0109 & 0.2187 \\ 0.2072 & 0.191 & 0.3514 & 0.0903 & 0.0109 & 0.0187 & 0.0075 & 0.0103 & 0.0009 & 0.0128 \\ 0.2929 & 0.2702 & 0.4492 & 0.2369 & 0.2006 & 0.0663 & 0.0197 & 0.0699 & 0.0167 & 0.0508 \\ 0.2667 & 0.3445 & 0.3727 & 0.142 & 0.1203 & 0.2112 & 0.0118 & 0.0419 & 0.01 & 0.059 \end{bmatrix} \tag{9}$$

Using equations below to calculate the impact of each factor, impact on each factor, centrality, and the reason factor.

$$f_i = \sum_{j=1}^{n} s_{ij} \ \ (i = 1,2, \dots, n)$$

$$e_i = \sum_{j=1}^{n} s_{ji} \ \ (i = 1,2, \dots, n)$$

$$x_i = f_i + e_i$$

$$y_i = f_i - e_i$$

Table 2 Results obtained using DEMATEL Model

Factors	*Impact of factor*	*Impact on factor*	*Centrality*	*Reason factor*	*Reason Or Result*
T1	0.647	2.5268	3.1738	-1.8798	Result
T2	0.4117	2.4974	2.9091	-2.0857	Result
T3	0.647	3.3151	3.9621	-2.6681	Result
T4	1.8145	1.1859	3.0004	0.6286	Reason
T5	2.2234	0.7859	3.0093	1.4375	Reason
T6	1.5801	0.9196	2.4997	0.6605	Reason
T7	1.5598	0.182	1.7418	1.3778	Reason
T8	0.901	0.6286	1.5296	0.2728	Reason
T9	1.6732	0.1487	1.8219	1.5245	Reason
T10	1.5801	0.8478	2.4279	0.7323	Reason

According to the Table 2, all human factors are result factors, and other ones are reason factors, because for the reason factor $y_i > 0$, factors T4, T5, T6, T7, T8, T9, T10 are considered as reason factors. For $y_i < 0$, factors T1, T2, and T3 are considered as result factors, which means that they are factors being influenced.

According to the Centrality, factors T1, T2, T3, T4, T5, T6, T10 have larger values, which means these factors are much more important than other ones. Among all reason factors, T4, T5, T6, T7, T9, and T10 have larger weight, so they are more important and need to be considered first.

6.5 Conclusion

This case study is to study the application of ergonomics in China. By studying a workshop in a manufacturing in Shanxi and applying DEMATEL Method, one can see the weight of all ergonomics factors being considered for potential improvement. Centrality refers to the importance of each factor. For factors with larger centralities, they are much more influential to the whole system, and they need to be considered first. In this case study, lighting system, vibration and noises have smaller centralities, and they may not be taken as priorities when improving the working environment in the workshop.

As for the reason factor, physical, psychological, and physiological human factors have reason factors smaller than zero, which means that they are result factors and do not have impact on other elements.

Chapter 7

Conclusion

In today's society, people's perception towards work is not limited to the safety environment of it, but also if the environment is comfortable. Enterprises in China are now aware of the importance of satisfying employees' physical, psychological, and physiological needs, while pursuing high efficiency. Merely rely on long work shift and increasing work load can only hurt the enterprise. Companies in China, such as the truck manufacturer in the case study, are fully aware of the power of ergonomics application and start to invest in new and user friendlier equipment. More scientific ergonomics analysis tools are utilized by enterprises in China to design their working environment to better meet their employees' needs. However, when applying methodologies, such as DEMATEL Model discussed in this research paper, it is important to be aware of the uniqueness of each subject being studied, and expertise is also needed through the evaluation process. Ergonomics is now gaining more popularities than it was ever before, and it is now being utilized not only to ensure the safety of workers, but also to design the work space better for workers to work in it comfortably.

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EDUCATION

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RELATED EXPERIENCE

Maker Sustainability Consulting Group Zhejiang, China
Senior Consultant June 2014-Present

- Senior Consultant seeking opportunities and transforming them into effective actions to make positive social impacts
- Conducted the target user assessment and data analysis for clients
- Integrated design thinking into sustainable and innovative solutions with community social impact for clients
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Pennsylvania Technology Assistant Program
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- Assisted Technical Specialist to conduct an energy consumption examination for a sawmill company
- Organized the database of over thousands of potential clients
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Humanitarian Engineering and Social Entrepreneurship program, Kenya & Zambia January 2013-Present

- Developed rainwater harvesting system design. Simulations and field test are conducted to test the design's efficiency and sustainability
- Won "The Gerard A. Hauser Prize", the overall best presentation prize in 2013 Undergraduate Research Exhibition
- Communicated with Kenyan local residents and merchants to gain knowledge of the local market's supply chain
- Initiated a mobile food cart social entrepreneurial venture in Kenya
- Developed the recipe, the preservation method, and the sensory evaluation in resource constrained context based on the literature review
- Standardized the construction manual for the affordable greenhouse venture
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- Authored, published, and presented a technical research paper in IEEE Global Humanitarian Technology Conference, "Gutter Design and Selection for Roof Rainwater Catchment Systems"
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LEADERSHIP

Chinese Students and Scholars Association, State College March 2013-March 2014
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- Produced short promotional videos using iMovie to market monthly themes and events
- Developed and supervised the production of various topical videos
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- Host bimonthly events for more than hundreds of Chinese students to let them express themselves freely
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- Coordinated efforts with various organizations and departments

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Computer: Advanced knowledge of Microsoft Excel, basic knowledge of Dreamweaver and SolidWorks, Basic knowledge of Photoshop and graphic design, C++, Mat Lab
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