

# Diagnostic Challenges in Applying Ergonomics in Developing Countries

John Abeysekera,  
Work Science Academy, Sweden

## Abstract:

**The science of Human Factors or Ergonomics applied in designing the work and machines to fit the human worker depends totally on measurements and methods. Diverse methodologies are used for evaluations, assessments and for diagnosing hazards, carrying out interventions and research. While advanced ergonomic methods are employed in Industrialized Countries (ICs) many challenges in diagnosis are experienced in Industrially Developing Countries (IDCs) due to the lack of knowhow and modern instrumentation. The cost factor is a major obstacle in IDCs.**

**A literature survey of the methodology trends in ICs and of the typical application, methods practiced in IDCs were carried out to ascertain the state of the art of the problem. A case study conducted in a developing country, Sri Lanka consisting of ergonomic assignments in 25 work establishments and a National Body Size survey elucidated the diagnostic challenges confronted in developing countries in applying ergonomics.**

**The literature reveals that latest ergonomic methodologies are used in ICs to carry out qualitative and quantitative tests in the field and in laboratories, do evaluations of human-machine systems, design physical work, environmental assessments and work organization issues. ICs are also engaged in sophisticated testing for research purposes e.g. human reliability analysis, task analysis, stress and mental load assessments, computer simulations and modeling, etc. However, IDCs trying to leap frog in acquiring modern technology are facing challenges in ergonomic methodology usage due to the limitations in economy, knowhow and instrumentation. The case study conducted in Sri Lanka has revealed that through traditional ergonomic methodology e.g. questionnaires and subjective assessment methods adequately reliable data can be collected for successful ergonomic interventions. Walk through surveys, interviewing techniques and checklists are cheap and popular in IDCs. However, the lack of ergonomic norms and expertise are disadvantages in IDCs in ergonomic interventions and research.**

**Methodologies developed by Toyota Japan in improving working conditions and productivity and reducing waste, e.g. 5S, Six Sigma, Lean manufacturing. Kaizen and QFD, which are based on ergonomic principles, are cost effective and recommended to be practiced in IDCs.**

## 1. Introduction

Human Factors or Ergonomics is defined as a study of human abilities and characteristics to design equipment, work environment and work for people. Human Factors is also defined as a science of measurements. It is required to know the inventory of evaluations that are needed in human work. Measurements are also needed to diagnose any prevailing hazards at work and the level of the hazard. Methods or techniques available are used for measurements of data collection concerning people, human race analysis, and evaluation of system design and research and in ergonomic intervention strategies.

Due to the lack of ergonomics norms, inadequacies of equipment and knowhow and the cost factor in measuring, assessments and equipment many challenges are encountered in applying ergonomics in developing countries.

There are diverse types of ergonomic assessments that have been developed by researchers as well as human factor specialists in the course of applications at work. The first objective in this study is to conduct a survey in literature and in textbooks on the available ergonomics assessment methods together with the relevant hazards. Emphasis in the literature search is placed on methods familiarly used in developing countries. It is also aimed to investigate the application obstacles prevalent in developing countries. After investigating the diagnostic challenges experienced in applying ergonomics, measures are suggested to solve or ease this problem.

## 2. Methods and Materials

The work carried out by different researchers in the past to classify ergonomic methodology

has shown that it is a very difficult task and perhaps not very useful or a fruitful exercise (Wilson J., and Corlett N., 1991). However to communicate information to engineers, designers and managers, classification in some way would be useful.

A literature search was carried out in text books and publications most of which refer to

Evaluations, measurements and analysis in developed countries (ICs)

In respect to developing countries (IDCs) there could be many challenges which are examined

in this paper. The main reason being the resources, equipment, knowhow in ergonomic applications in a developing country are poor and lacking. The aim is to prevent any inadequacies by refining and adapting the methodology to be used with ease. To highlight any pitfalls and inadequacies in methodologies adopted in IDCs a case study was carried out in Sri Lanka (a developing country) which included the following two investigations.

- Twenty five work establishments were surveyed and evaluated with a view to examine the obstacles and challenges in methodology selecting and evaluating.
- The methodology to be followed in carrying out a body size survey in a developing country could be a really challenging task. The case study also reports the obstacles faced in carrying out a National Anthropometric Survey in Sri Lanka the first of its kind ever to be carried out in this country.

### 3. Results

#### 3.1 Literature

The literature revealed that ergonomic methodology is divided into three major areas, viz.

- (a) Methods used in data collection of humans, e.g. anatomical, physiological and psychological parameters.
- (b) Methods of application of the data to design
- © Methods of evaluation of designs. Evaluation implies measurements before and after application of the data.

Ergonomic assessments consist of a mixture of qualitative and quantitative testing, which can be interpreted as subjective and objective assessments respectively. These tests are conducted either in the field or in a laboratory. Some qualitative data collected are from questionnaires, observational surveys, **discussions, and interviews.**

Observational methods include:

- Experimental: Laboratory tests, simulations and field experiments
- Data based methods: Journals, books, advice from experts
- Subjective methods: Questionnaire, Interviews, Ratings and Ranking

Data are also collected from work place records and photographs. Objective or quantitative data include measurements of workplace, environmental variables and body size measurements of people. In addition computer modeling, simulation and test trials are methods employed in design and evaluations.

In the text book on 'Evaluation of Human Work', John Wilson and Nigel Corlett, (1991) have attempted to classify the methods, techniques and measurements in ergonomics. In Table 1 more important classifications are listed. Instrumentation is shown against each method where relevant which are suggested by the author from the experiences gathered as a teacher in ergonomics at Luleå University Sweden from 1984 to 2002.

CLASS OF METHODOLOGY	TECHNIQUES	INTRUMENTATION
<b>1.Information from people</b>		
-Direct Observations	Check lists, Walk through Surveys Housekeeping Exercise (TUTTAVA) (Saari J and Naesaenen, 1989)	-
- Indirect Observations	Surveys and Questionnaires	-
- Cognitive Performance	Aptitude and Perceptual tasks	Aptitude test, Apparatus
- Expert Knowledge	Interviews	-
- Physical Measurements	Body Sizes, Photographs	Anthropometer
- Physiological Measurements	Electrocardiography (ECG) Electromyography (EMG) Electroencephalography EEG)	ECG, EMG EEG
-Ventilatory function	Lung Function Test	Spirometer/ Peak Flow Meter
<b>2. Evaluation of Human-Machine System</b>		
-Task Analysis	Cognitive, Hierarchical, Link & Job Analysis	-
-Data bases, Archives	Personal records, Standards	-
-Interface Evaluations	User trials, Expert Analysis	-
-Electronic monitoring	On-line (Performance)	-
-Simulation	Computer Aided Design (CAD)	Computer, SAMMIE
-Human Reliability Analysis	SHERPA, THERP, HEART	Comp-Software
-Method Study	Filming	Video Camera
-Accident Analysis	Archive reports, Interviews	-
-Work Measurement	Time Study	-
-Cost benefit Analysis	Investment returns, Productivity	-
<b>3. Analysis of Work and its effects</b>		
-Physical Work Load	Observations, Borg Scale,	-
-Posture Analysis	Biomechanical Models, OWAS	-
-Physiological Analysis	Heart Rate, Oxygen Uptake, ECG, EMG Edholms Scale in Bridger, 1996 Oxygen Consumption Measurement	(Oxygen analyser (Bicycle ergometer (Physiometer (Oxylog
-Hearing Loss	Audiometry	Audiometer
-Mental work load	Subjective Assessment, Psychological responses	- -
-Stress Assessment	Indirect observation	-
-Subjective Assessment	Physiological techniques	-
-Performance Measures	Speech intelligibility, And Mental Tasks	Psychomotor -
-Response Measures	Sweat rate, Body temperature Heart rate, Visual acuity, Hearing Loss	(Contact and core (thermometers, Pulse (Meter, Audiometer
<b>4. Physical Environment Assessments</b>		
-Lighting	Illumination, Luminance, Contrast	Hagner Photometer
-Thermal	Ambient temperature, Humidity Radiant temperature, Air velocity	(Wet and Dry Bulb. (Globe thermometer (Whirling Hygrometer (Thermal Climate (assessment kit)
-Noise and Vibration	Sound levels, Frequency Analysis Vibration levels	(Sound level Meter (Frequency Analyzer ( Accelerometer
<b>5.Organizational environment Assessment</b>		
-Indirect observation	Rating and Ranking,	-
<b>6.Design and Implementation</b>		
-User tests	Observations	-
-Expert Analysis	Walk through Audits	-
-Participation Method	Design and Follow up	-

Table 1. Ergonomic Methodology Classification with Techniques and suggested Instrumentation

The validity and reliability of methods are said to be application specific. Meister, D., (1986) has reported of a questionnaire survey for testing and evaluation of the method. Those methods, which rated consistently highly on all three criteria of frequency, usefulness and ease of use, were those of indirect observation in questionnaires and rating scales for instance. The use of two or more methods to improve efficiency, completeness and insight of study weaknesses in one method can be balanced by strengths in another (Denzin, N., 1970).

In addition to traditional methods used in ergonomic intervention and evaluations Toyota, Japan has introduced new strategies and methods which had a magical effect in improving work stations and tools. John Abeysekera, (2012) in his study on 'Visions of Ergonomics for globally operating business' describes Toyotas success stories after adopting the following methods.

- Lean Manufacturing: Strategies employed to increase efficiency and decreasing waste using empirical methods
- Kaizen: A humanized approach to work with the aim of increasing productivity
- Six Sigma: Quality improvement methodologies such as Quality, TQM and Zero Defects
- 5S: A popular Japanese methodology aimed to achieve the objectives in good housekeeping
- Quality Function Deployment (QFD): By employing this method the human needs are systematically matched with product characteristics. The QFD analysis fulfills the customer needs

According to this study these new strategies adopted by Toyota are based on principles of ergonomics and can be categorized as Ergonomic Methods.

Since the methods and obstacles faced in carrying out body sizes or anthropometric survey are described in the case study conducted in Sri Lanka, findings in literature on anthropometric surveys are reported as follows.

Anthropometry is the science of measurement of the human body considered in the application of design. The literature on methodology adopted in body size surveys reveals both traditional and modern methods. John Roebuck Jr. (1993) reported a technological revolution occurring in the methods of anthropometry. He says that traditional methods are still important for maintaining comparability of measurements. With the advent of computers, new opto-electronic measurement devices gave rise to the development of new methods. Anthropometry also helps to evaluate postures, specify clearing operator fit in vehicles, design of tools and handles, clothing design, seat design etc., (Roebuck .A. et al, 1975).

Human Factors analyses of workplaces require more than simply a description of the size and shape of people in the standard anthropometric postures. These analyses depend on predictions of what people will look in non-standard applications-specific operating postures or while relaxed in various types of seats, couches and other body support devices.

Past and current deficiencies in anthropometric data gathering, reporting and application created new demands for more comprehensive and integrated data. Notable examples include 3D measurements of body surface contours and landmarks, location of internal joint centers of rotation. The development of computer models has offered new opportunities for using large, central mathematical data bases and more integrated comprehensive representations of the human form that are potentially useful for several purposes such as the design of clothing, work space, tools and equipment.

The evolution of new computer modeling techniques has been accompanied by parallel development in new measurement techniques e.g. lasers, stereo video, structured light, magnetic resonance image (MRI) complement the new data needs. But they pose a problem in comparing and understanding the data produced by the older manual methods. Development of highly capable software and methods for data compression are some potential solutions to the problems.

### 3.2 Case Study Findings

#### 3.2.1 Work Establishment Surveys

Out of the 25 work establishments surveyed in Sri Lanka almost 90% were from the apparel industry. Apparel exports in Sri Lanka supersede all other exports and therefore the apparel industry employs the largest number of employees in any one industry. The products manufactured, processes employed, hazards encountered and methods of analysis are summarized in Table 2

PRODUCTS	PROCESSES	HAZARDS	METHODOLOGIES
Fabric	Sewing	(Manual Handling	(Observational Surveys
Sportswear	Knitting	(Posture Discomfort	(Questionnaires
Lace	Weaving	(High Noise Level	(Interviews
Undergarments	Cutting	(Thermal Discomfort	(Work Place Analysis, 1989
Leisure apparel	Line Production	(Overcrowding	(ILO Check Points, 1996
Garments	Dyeing	(Glare	(Detections using Senses
Yarn	Inspection / Ironing	(Back Pain	
	Packing		
	RM and FG Handling		

Table 2: Processes, Hazards and Methods in Surveys in the apparel Industries in Sri Lanka

### 3.2.2 Body Size Survey

A National Anthropometric Survey of workers in Sri Lanka was carried out during a period of 16 months in 1982/83 by three trained investigators. Prior to the actual survey a pilot survey for 3 weeks was conducted on 100 workers. The accuracy of measurement was checked and confirmed by re-checking measurements on a sample of 10 out of 100 subjects.. A total of 90 body measurements to cover anthropometric information for designers (Boltin et al 1973, Hobbs 1973) were taken. A total of 724 subjects between the ages of 21 and 51 years included 60.5% males and 39.5% females from 24 districts selected at proportional basis and subjects from 80 work establishments were selected at random. The sick and disabled persons were excluded.

Simple and accurate measuring instruments were used as follows: Harpendum anthropometer took 50% linear measurements. Circumferences were measured using a canvas flexible measuring tape. Calipers used for face and head measurements. Steel tape (not flexible) was also used for few measurements. The 90 measurements included the weight, 28 standing, 15 seated, 12 circumferences, 25 head, 4 hand and 5 foot and the balance measurements were derived.

Measurements were carried out in the respective work places. Two members of the team did the measurements alternately, which reduced the boredom. Data were recorded on a designed form. The recorder verbally confirmed each measurement. Measurements were carried out on the left side of the subject. All data were scrutinized for omission and obvious errors. (Abeysekera J.D.A and Shahnava H. 1987).

## 4. Discussion

The impact of the diagnostic challenges in applying ergonomics in developing countries was investigated by conducting a case study in Sri Lanka (a developing country in Asia). The case study included ergonomic surveys carried out in 25 work establishments in the apparel industry (an organized progressive industry) and a National Anthropometric Survey. The literature on ergonomic methodology reveals both traditional and modern methods of analysis used in different parts of the world. Since ergonomics is not popular or sometimes unknown in many developing countries most methods reported in the literature are from industrialized countries (ICs).

Salient features in the methods practiced in ICs are quicker to perform, more expensive, technologically more advanced and ideal in research. Out of the three major areas viz. human data, application and evaluation in design where subjective assessment or qualitative data are collected more traditional methods are used. The few IDC countries practicing ergonomics also adopt these methods, as they are less expensive. For example subjective tests like questionnaires, observational surveys, discussions and interviews do not require sophisticated instrumentation. However objective measurements e.g. heart rates, energy expenditure, etc., physical environment measurements e.g. lighting, thermal and noise assessments, body size measurements, etc. are carried out using modern equipment and methods in ICs. In IDCs most of the above tests are conducted using low cost traditional instruments and procedures.

The following modern methods are more common and regularly practiced in ICs.

- Experimental simulation,
- Evaluation of perceptual cognitive tasks,
- Evaluation of human machine systems,
- Computer analysis including CAD/CAM,
- Human reliability analysis,
- Mental work load assessments (EEG, Electroencephalography),
- Muscular functions using Electromyography (EMG),
- Functions of the heart using Electrocardiography (ECG), etc.

In the case study carried out in Sri Lanka it is seen that hardly any expensive instrumentation has been used in carrying out ergonomic work establishment surveys. This is a disadvantage in research work.

The National Anthropometric Survey in Sri Lanka there were many limitations such as (a) Sample size not statistically adequate (726 subjects), (b) Longer time taken for measurements (c) Possible deficiencies in taking and recording measurements, etc. The pilot survey and experience gathered in carrying out the survey enabled to control the above limitations to the minimum.

For research purposes appropriate instrumentation are preferable and sometimes essential. These facilities however are available in countries with advanced technology. The other advantages in modern methods are quick and comprehensive surveys and evaluations.

In the body size survey only traditional measuring instruments and techniques have been used. Although the cost is low, deficiencies could occur in collecting, analyzing and applying body size data using traditional techniques. When precision instruments are not used data collected from such surveys cannot be reliably compared with other international data. These are some of the challenges and obstacles confronted by IDCs in ergonomic applications. However, IDCs, which try to leapfrog in development work, are at present experimenting with the modern methods.

The transfer of technology from ICs has brought with it different levels of technology to IDCs. The traditional ergonomic methods used in IDCs cannot tackle adequately the problems resulting from advanced technology. This is an additional challenge experienced in IDCs. A good example is the Bhopal catastrophe in India where thousands were killed from a leak of the poisonous gas in a pesticide plant. The technology was brought from US, Union Carbide. During the Bhopal accident, investigations it had been revealed that

Union Carbide spokesman have since explained that safety equipment and procedures in Bhopal were less sophisticated in part to provide more jobs. This is an example of a transfer process, which does not consider all aspects of a total technological system and therefore an incomplete transfer. (Abeysekera, J. D.A., 1990)

## 5. Conclusions and Recommendations

This paper examined the obstacles experienced in developing countries to carry out ergonomic assessments in design, application and evaluation. The following findings are based on the case study in Sri Lanka (a developing country).

- Methods should be cheap to carry out and should not involve sophisticated and expensive instrumentation
- Subjective assessments should be employed as far as possible which provide preferences, ratings, rankings and scaling
- Questionnaire surveys: A most common method should be employed to collect subjective data
- The use of check-lists containing lists of items that are expected to occur and are checked by an expert or worker
- Minimize the use of a laboratory analysis and depend more on the use of the five senses to get detailed information on the spot
- The use of the internet and literature in selecting the correct methodology can compensate the knowhow deficiencies in developing countries
- The data collected through Interviews lack rigidity in questions and answers. Interviewer has more discretion and flexibility
- Walk through surveys provide information through observations and controls the cost to the minimum.

But the results of the case study in Sri Lanka show that even using traditional methods useful ergonomic measurements and evaluations are possible. In this respect it is recommended that IDCs continue to adopt methods such as subjective assessments, questionnaires, walk through surveys, interviews, posture analysis using OWAS method, work rate analysis using scales such as Borg's, Metabolic rate analysis using Edholm's Scale, check lists such as ILO Ergonomic Check Points, Ergonomic Work Place Analysis which compares the experts and workers evaluations, Detections using the five senses, much data can be collected and interpreted successfully.

The methods introduced by Japan e.g. 5S, Six Sigma, QFD, Kaizen and Lean have been proved appropriate in ergonomic evaluations and interventions in IDCs. (Abeysekera, J, 2011). Since IDCs are desperately trying to acquire modern technology and IDCs are labour intensive more fool-proof safety systems, safety methodologies and maintenance procedures are needed as people at risk are greater in number (Abeysekera, J.D.A, 1990)

## 6. References

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- Wilson John R et al (1991) Abbreviations
- Borg's Ratings of Perceived Exertion (RPE)
  - ECG: Electrocardiography
  - EMG: Electromyography
  - EEG: Electroencephalography
  - HEART: Human Error Assessment and Reduction Technique
  - OWAS Working Posture Analysis developed by Ovako Oy in conjunction with Finish Institute of Occupational Health
  - SAMMIE: System for Aiding Man-Machine Interaction Evaluation
  - SHERPA: Systematic Human Error Reduction and Production Approach
  - THERP: Technique for Human Error Rate Prediction