

# **Ergonomics in Industrially Developing Countries**

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Ergonomics in developing countries is now a recognized area of activity but whether it differs from the traditional study of ergonomics has not been made clear. This paper aims to provide a systematic review of the issues and activities in the application of ergonomics in industrially developing countries, considering whether there are differences between ergonomics in industrialized countries and in developing countries; in terms of philosophy, aims and approach. Can ergonomics be prescribed in a 'pure' form according to its western methodology, or is it to be adapted to the situation context? Ergonomics as an important discipline in overseas development is discussed, both as an approach to individual differences (micro-ergonomics) and as an approach to the broader socio-cultural factors (macro-ergonomics).

## **1. Introduction**

In industrially developing countries (IDCs) working practices in unsafe environments, both in industrial and rural workplaces, are not uncommon. Shahnava (1) suggested that the rate of accidents and injuries at work in IDCs is ten times that of industrialized countries (ICs). There are many factors that have a detrimental effect on the safety, comfort and performance of workers. The underlying causes are usually economic, socio-cultural or climatic in their origins, often combined with inappropriate technology transfer (Table 1). Poor occupational health as an almost inevitable consequence can often be identified as a predominant factor in perpetuating poverty and low levels of productivity. A vicious circle often exists where wages are low because of low productivity, living standards do not improve and disease cannot be overcome (Figure 1). The workers' capacity is held down and, as a result, productivity cannot be increased. Ergonomics, with its multi-disciplinary approach, can help break this cycle by promoting safer workplaces and improving the health of workers by reducing occupational diseases, and thereby enabling sustainable improvements in productivity.

Ergonomics, as a scientific discipline, is international in its scope and its aims of improving comfort, safety and performance can play a unique role in development. The methodology is essentially the same for ICs and IDCs, but for IDCs a greater sensitivity to ecological and cultural factors may be required. Neither ICs nor IDCs are homogenous and any successful ergonomics intervention will depend upon acknowledgment of this fact. Whilst major differences between ICs and IDCs clearly exist, (see Table 2), differences between IDCs themselves should not be overlooked and may be comparable in importance.

When implementing ergonomics in IDCs, issues that are unlikely to arise in traditional IC ergonomics analyses must be considered. Lippert (6) stated it 'will require a broadening of our traditional horizons to include an awareness of the cultural, social and economic contexts in which man performs work'. Thus the context of ergonomics will be more focus dependent. Questions may be asked: will quick industrialization lead to growth, or to rural poverty and urban migration? (7, 8). Human capital may be a country's greatest resource, so care must be taken that higher levels of mechanization do not result in unemployment or under utilization of this resource. Whilst Western technology is often concerned with maximum output and intensive automation, this is not necessarily the case in IDCs where it is desirable to use the maximum amount of labor and still make the industrial enterprises economically viable (9). Moray (10) noted that 'ergonomic solutions which reduce the amount of manual labor through automation are not acceptable solutions for a technically unsophisticated population where manual labor may be the only source of income'. Rather than high-level technological intervention, the need may be for better tools and non motorized mechanization. This would make more effective use of the mechanical energy available (8) and would be more appropriate than transferring expensive and inappropriate machinery from ICs. In such interventions, simple improvements according to local priorities can be far more effective and acceptable than imposing major changes, tasks and operations that may look appealing to governments and sponsors but which are ultimately rejected by the target communities. Small local projects are thus often a more effective means to enable ergonomics to focus on relatively low cost solutions and ensure that greater importance is attached to the associated cultural factors (11, 12).

## 2. Technology Transfer

Technology transfer has been defined as ‘the process of introducing an existing technological knowledge where it has not previously been conceived or implemented’ (13). Technology is often seen by IDCs as a major tool in achieving accelerated economic development. ICs are keen to transfer their technology in the belief that it is in their interest to do so, both in order to maintain a sphere of influence in the recipient country (14) and to promote trade and a marketplace within that country. For technology to be transferred successfully it must be appropriate, that is, it must reflect the environment in which it is to be utilized (15). Introducing inappropriate technology can be both socially and economically destructive through failure to meet its potential. This can occur from under-utilization of machinery, equipment deterioration, frequent and costly repairs, low productivity, poor product quality, high rates of accidents, occupational diseases, and low motivation from a fear, distrust or rejection of the technology (2, 16). For example, Dibbits (17) reported how sound engineering projects such as redesigned plows in Zambia were rejected because the human factor had not been taken into account. The new ox-drawn plows reduced the draught force required and increased the quality of work, yet the farmers found them too heavy and did not use them.

An example where technology transfer failed on a disastrous scale was at Bhopal in India when on the night of 2/3 December 1984 a cloud of the toxic gas methyl isocyanate (MIC) was released into the environment from the Union Carbide pesticide plant, killing an estimated eight thousand people and injuring an estimated 3 million others (18). A number of ergonomics issues were ignored when the technology was transferred, thereby contributing to the disaster. Cost was the overriding consideration; health and safety factors were compromised. Many operations that were automated in similar plants in ICs were performed manually in the Bhopal plant. For example, safety monitoring devices that should have been automated, were inspected visually by the Bhopal operators and many of the gauges were unreliable or out of order. Consequently, the operators were unaware of the pending disaster until it was too late. Furthermore, operators had received insufficient safety training, and did not have proper access to safety information as the manuals were written in English, not in the indigenous language (19). After the explosion had occurred, the management and operators had inadequate information on the hazard potential of the plant, hence their inability to provide relief agencies with the essential technical information (20). In summary a catalogue of errors occurred that could have

been avoided if the technology had been transferred appropriately with ergonomics factors incorporated.

### 3. Macro and Micro Ergonomics

To minimize potential problems of transferring technology, the holistic systems-based ergonomics approach is essential. Any intervention involving a tool, machinery or a system must adopt this ergonomics philosophy for the full benefit to be realized. Indeed, Meshkati (21) suggested that ‘only through a thorough ergonomics analysis... can provision be made for effective alternatives to ensure the appropriateness of transferred technology and its safe and efficient utilization by the recipient country.’

The application of ergonomics in IDCs must consider two principal areas; macro-ergonomics and micro-ergonomics (Table 3). Whilst macro-ergonomics is concerned with the broader socio-cultural and organizational *system* issues, micro-ergonomics is concerned with the individual, physiological and psychological aspects. Often the ergonomics of technology transfer will be considered only at the micro level. It is entirely possible to do an outstanding job of micro-ergonomically designed systems components, modules and subsystems, yet fail to reach desired systems effective goals (22). To ensure both full integration of imported technology to an IDC and effective incorporation of ergonomics into any workplace or occupational situation, the macro and micro ergonomics issues as discussed below, must be addressed.

#### 3.1 Macro Ergonomics

##### 3.1.1 Culture

Culture is ‘the way of life of people’ (15). Culture is reflected through beliefs and attitudes towards work organization, motivation, working habits, group dynamics, religion and customs (13). The Protestant work ethic of ICs is largely alien to IDCs. It has been said that traditionally agricultural orientated workers reacting to imported technology ‘have not internalized the technological culture’ (23). In India, a job is often regarded as a family responsibility or a collective task; attempts to bring in anyone from outside the family can often cause resentment and resistance (24).

In communities where traditional customs have been observed over the centuries, a fear or resistance to changes that new technology brings is to be expected. Often the fear of industrial automation will be the fear of unemployment. Whilst in ICs automation is used

to reduce labor costs by using the minimum amount of labor, in IDCs the maximum amount of labor utilization is desired provided that it is not demeaning or degrading. Fear of technology can continue after installation. Replacement parts may need importing from the country of manufacture and hence be expensive and/ or difficult to obtain. A fear of breakages or ignorance of maintenance needs will become manifest in under-utilization, inefficiency and rejection. The ergonomist can reduce this resistance and fear of change by demonstrating that the new process is more rewarding (9). S/he can involve the anticipated user population, creating a feel of ownership towards the new technology (25) by using education, appropriate training methods and a participative approach.

Religion in IDCs tends to play an important part in peoples lives. Consequently religious observances must be considered when transferring technology. An interesting example of failure to do this was the cause of the Indian Mutiny in 1857. New rifles were introduced to the Indian army, with new cartridges. To load the rifle, the ends of the cartridges had to be bitten off. They were allegedly greased with cow and pig fat; Hindus will not eat cows which they consider sacred, whilst Muslims will not touch 'unclean' pigs.

In Hinduism and Buddhism, Karma, (crudely the laws of cause and effect) helps explain misfortune. Within the caste system, the inferior social status of 'the worker' tends to reinforce these beliefs that misfortune is a personal responsibility (26). In Islam, accidents may be attributed to *Inshallah*- 'God's will'. In Nigeria, *Voodoo* and *Juju* charms often replace safety tools; Sanwo (27) cites an example of a tree climber preferring to use his charms and *voodoo* than use the safety equipment provided by his employer.

What is considered socially acceptable in ICs may be abhorrent in IDCs (and vice-versa). In India, for example, a western style safety poster, featuring a scantily clad woman had to be withdrawn because it was considered too obscene (28).

### 3.1.2 Organization

Organizational transfer is often insufficient or inappropriate. Ong (13) noted that many individuals may have difficulties in adjusting to new techniques, management and organization associated with technologies from ICs. Wisner (7) refers to incomplete transfer in the organization of maintenance. The supplier often does not provide a realistic description of the maintenance organization that should be transferred, consequently it is left to the ingenuity of local artisans.

It is a mistaken belief that the organizational cultures found in many ICs are inherently transferable. Whilst organizations in ICs are geared towards clearly defined work tasks and rationalized work, in IDCs the definition of the work task is frequently made by the individual (4). Hofstede (29) comments that the concept of achievement is hardly translatable from English into any other language. Similarly, Maslow's 'Hierarchy of Needs' (30) is not a universal human motivational process. Where religions such as Buddhism or Hinduism predominate in cultures, the need is not for 'self-actualization' at work, but for 'enlightenment' and freedom from *Samsara*, the wheel of life. Meshkati (21) suggests a proactive and systematic approach to managerial and organizational transfer, in order to ensure a complete and appropriate organizational structure that will work with both the technology introduced and the new users.

### *3.1.3 Infrastructure*

Technology from ICs is likely to fail in IDCs if attention to the infrastructure is neglected. For example pure water or a stable electricity supply cannot be relied on everywhere in the world (31). Comprehensive transport systems cannot be depended upon: in the late 1980's whilst the USA had one vehicle for every 1.4 people, Ethiopia had one vehicle for every 100 people and China one for every 1400 (32). Poor roads will damage vehicles, and any intervention involving transport for its success must ensure that vehicles are appropriate (e.g. four-wheel drive) and sufficiently resilient. Often methods of communication are also inadequate (13). Overcrowded and makeshift workplaces are further infrastructural weaknesses. Infrastructure, however, is often a reflection of the economic state of the country, which in turn is dependent on external investment from other countries. Such investment must be targeted to make optimum use of human capital before other benefits can be realized.

### *3.1.4 Climate*

The hot, humid, tropical environments of many IDCs may not be suitable for certain technologies to be transferred. Sen (28) illustrates how public buses in Calcutta are copies of London double-decker buses. Originally designed for the temperate English climate, they are wholly unsuitable for the tropical Indian heat. European equipment may not be designed for use in extreme climatic conditions and may therefore suffer damage if not complete failure. With insufficient operational information and inadequate availability of spare parts for maintenance this situation may be exacerbated (2). Problems with rusting,

fluidity of lubricators, and the performance of glues may be encountered (7). Additional or improved technology such as air conditioning and specialist lubricants may be required to ensure imported machinery operates effectively in tropical environments.

### *3.1.5 Environment*

In IDCs pressures may be placed on natural resources. Depletion of fuelwood is often common and in many communities up to 80% of a family's cooking and heating energy can come from plant material (33). Ecological ergonomic interventions can help reduce the demands on these scarce resources. Igbeka (34) described an improved stove for a traditional food processing activity that, as well as reducing drudgery, significantly reduced the demand for fuel.

Water scarcity is often a problem in both rural and urban communities. Women predominantly, but also children, often have to travel long distances carrying water from the nearest source to the household. This is a time consuming and arduous task. Ergonomics interventions may provide opportunities for reducing the drudgery involved in these tasks (35,36). When water pumps are introduced to communities it is important to ensure they are suitably designed to accommodate the strength and reach of children who often collect much of the water.

The use of chemicals in agriculture may have detrimental environmental effects not only on soil, water, air quality but also on health. When used in large quantities they can have an impact on the food chain through pesticide residues in food (37). Pesticide misuse is well documented (38) and often this will be due to a lack of knowledge or training about the chemicals, or inappropriate labeling of containers. In Ghana, anecdotal evidence from people involved in chemical sales suggest that farmers taste the pesticide before they buy it to verify its strength. Similarly in Thailand, farmers have been reported to test the concentration of pesticides by dabbing it on their tongues (39).

## *3.2 Micro Ergonomics*

### *3.2.1 Anthropometrics*

When technology is to be transferred, it is essential to consider the anthropometric characteristics of the intended users. Comparative studies of anthropometric data show that for almost every part of the human body there are differences between populations in IDCs and ICs (2). For example, the forward reach of the 50<sup>th</sup> percentile North European

male is 870mm, whilst that of the 50<sup>th</sup> percentile Latin American-Indian male is 780mm (40). Failure to accommodate this difference in control panel design could have serious implications for both the safety and comfort of the South American operator.

It is particularly important to ensure personal protective equipment is anthropometrically suitable if it is to be adopted. If it is not comfortable, it is unlikely to be worn. The problems of anthropometrics are compounded by the fact that body measurements can differ significantly between rural and urban populations. The origins of such differences between IDCs and ICs are suggested by Abeysekera (41) to be genetic, climatic, altitude, level of activity, nutrition, and living standards.

### *3.2.2 Nutrition*

In IDCs many workers suffer from under-nourishment and malnutrition. Workers in IDCs have been found to expend more energy than could be derived from the food they could purchase from their wages (28). Studies indicate that people in IDCs can respond to low energy intakes by slowing growth and achieving a reduced stature. Many populations live apparently healthy lives on energy intakes of about 60% of present FAO/WHO standards (42). A relation between malnutrition and work efficiency, if any, may warrant investigation. The ergonomist may, therefore, need to promote the importance of an efficient and balanced diet and encourage employers to provide subsidized nutritional supplements for their workers as a means to improve both human productivity and quality of life.

### *3.2.3 Heat*

IDCs are often characterized by hot and humid tropical environments. Excessive heat affects workers' performance and precipitates illnesses such as nausea, muscle spasms and, in extreme cases, heat stroke. A hot, humid working environment can increase the intake of toxic substances through skin absorption (43). A study of Thai industries reported heat problems existed in 24% of small enterprises (44).

Kartawikarta (45) states that 'the application of ergonomics through a good choice of location, tools and methods of work which are suitable to the tropical environment is essential to reduce the negative effects of the climate and thus to achieve efficiency and well-being at work.' The importance of work-rest cycles in tropical climates is therefore implicated and must be considered in relation to productivity and health. Perceptions of thermal comfort may also differ to Western norms (2). Improved ventilation to increase



evaporative cooling from sweating and the adequate supply of clean water and salt to prevent the undesirable effects of dehydration may often be required (46). Any personal protective equipment which may be necessary should also consider the increased potential of heat stress.

#### *3.2.4 Posture*

Sen (28) pointed out that posture in IDCs (specifically India) is often different from that in ICs. Squatting and sitting on the floor are common work postures and many indigenously designed machines such as lathes and potters wheels are designed for use in this fashion.

In West African agriculture, the primary hand tools are predominantly the short handled hoe and the cutlass. Both these tools require stooping for use, a posture that is frequently adopted for many activities in the region, indeed some activities such as ridge making and mound making demand much bending to achieve the desired objective (47). Attempts to introduce tools that do not require apparently awkward postures have mostly failed (48). Wood (49) suggested that underlying design assumptions, based on western work postures, fail to transfer to their full potential where the majority of the population prefer to squat. This may also be true where they prefer to bend. Hence, it may be necessary to conduct ergonomics research into the indigenous working habits rather than attempting to apply a technique rooted in a different culture and based on different data (28, 49).

#### *3.2.5 Psychological- Cognitive Differences: Language and Literacy*

In many IDCs the level of illiteracy is well over 50% (32). The consequences of this will be apparent when technology for a literate population is imported into a country where the users of such technology are unable to read translated instructions, training and safety manuals. Lack of education will often appear as ignorance with traditional practices observed for no other reason than ‘that is the way it has always been done.’

Where many different languages are spoken (for example India has more than 150 different official languages and a plethora of dialects), it is almost impossible to translate technical literature for all potential users. The assimilation of knowledge and know-how will be further limited by local people not understanding the language of foreign experts (13). The ergonomist can provide illustrated job aids which are culturally and socially sensitive, obeying local norms and stereotypes. In addition, Chapanis (24) stressed the importance of good training and evaluation, suggesting that in the need to ‘save face’ Asian students rarely ask questions.

### 3.2.6 Psychological- Cognitive Differences: Stereotypes

Stereotypes are not necessarily cross-cultural. Whilst the color red is universally associated with *stop* in ICs, in China it is not so definitely associated, red being a color of happiness and prosperity. Similarly, it is considered auspicious by Indians (2). Whilst the stereotype for switches in many countries is taken to be the *up* position for ‘off’ and *down* for ‘on,’ there are many places where the opposite can be found. Road signs, which obey conventional stereotypes are not universally understood. For example, in one study the sign for *no horn* was interpreted as *blow your horn please* (2).

## 4. Ergonomics in rural development

Perhaps the single most important difference between ICs and IDCs is the prevalence of agriculture, especially subsistence farming. Rural communities provide the basic economic output for many IDCs in the production of food for rural and urban communities and of cash crops for export to earn foreign currency (50). Agricultural development is therefore usually the forerunner to industrial development and to more dependable methods of wealth creation (11).

Manual labor predominates in IDCs; in agriculture nearly 70% of the energy used for crop production activities in Asia is of human origin and in Sub-Saharan Africa almost 90% (51). Perhaps the majority of ergonomics work in IDCs has been concerned with the evaluation and design of hand tools (2, 52). It is in this area that ergonomics can most benefit rural agricultural communities, in helping to reduce drudgery and discomfort and increase productivity and well-being.

Throughout history, hand tools have remained basically the same. It has been suggested that this arises from the perception that many years of experience will have developed the optimum design in hand tools (53). Yet hand tools are involved in many accidents, with the upper extremities being injured more often than any other part of the body (54). The majority of subsistence farmers in developing countries are women (55) whose average maximal grip is 65% that of men (56). It is thus apparent that there must be scope for ergonomics improvements to many hand tools particularly those used by women.

The focus on hand tool evaluation and redesign will be much the same in IDCs as ICs. The main objective however, as with any ergonomics intervention in IDCs, is one of a participatory approach, putting ‘people first’ (Table 4). This approach has been shown to be most effective in successfully introducing improvements to working situations by

Chambers et al. (57). Whether it is redesigning handtools or changing working practices, they highlight the need to empower the local community; an appropriate role for the ergonomist would then be to facilitate solutions as a convenor, catalyst and adviser.

## 5. Conclusions

Much of the literature on the practice of ergonomics in IDCs has been specific to technology transfer. In many IDCs, agriculture is a major contributor to their GDP, yet there has been little research into the benefits likely to accrue from introducing ergonomics into the rural agricultural sectors. Within a participatory framework of developing small-scale solutions to problems, the ergonomics approach can be expected to return far greater benefits to IDCs than those accruing from large scale capital projects.

From the examples given in this paper it can be seen that the scope and approach of ergonomics will essentially not differ between ICs and IDCs. The major differences will be between the IDCs themselves rather than between the 'North' and 'South'. When considering implementing ergonomics in IDCs, to treat them as a single homogenous unit is to invite failure. The differences therefore will be in the application of ergonomics rather than in its methodology. For ergonomics to be successful in IDCs, it must be 'applied', i.e. adapted to the situational context. The ergonomist must go beyond the traditional 'pure' methodology and consider additional factors such as the culture in which s/he is working. Can literacy be assumed? Are western stereotypes appropriate? Does the prescribed solution depend upon Western norms? (For example will a rural Indian worker use a chair to work when his normal resting posture is to squat on his haunches.) Perhaps most importantly, if ergonomics is to be successfully introduced, the necessity of low-cost solutions and consideration of cultural factors is paramount.

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Table 1 Examples of problems found in IDCs (2)

Problem	Suggested immediate causes	Underlying cause
Low machine utilization	Maintenance problems	Lack of spare parts
Lack of skills	Lack of appropriate training	Poor management
Low motivation in the workforce	High turnover of staff and pressure from unemployment	Infrastructural weaknesses
Excessive environmental and physical loads	Tropical climate	Activities and tools not designed for conditions
High accident rates	Inappropriate working practices and poor design of machines and tools	Poor occupational health

Table 2 Differences between Industrialized and Industrially developing countries. (4,5)

Industrialized Countries (ICs)	Industrially Developing Countries (IDCs)
Prevalence of manufacturing industry and service sector	Prevalence of agriculture
Clearly defined work tasks, rationalized work	Definition of work task by the individual
Mass production; little contact between consumer and manufacturer	Closer contact between consumer and manufacturer
Workers familiar with technology	Little contact with technology
Homogeneous level of technology, productivity and working conditions	Wide range of technology, productivity and working conditions in different regions and economic sectors
Work for social identification	Work for subsistence
Unions interested in safety	Unions mainly interested in wages and income issues
Manual labor content low	Manual labor content high
Little man-machine interaction	Great deal of man-machine interaction

Table 3 Macro- and Micro- ergonomic factors to be considered when applying ergonomics in IDCs

Macro ergonomics	Micro ergonomics
<input type="checkbox"/> Culture	<input type="checkbox"/> Physiological
<input type="checkbox"/> Organization	<ul style="list-style-type: none"> <li>• Anthropometric</li> </ul>
<input type="checkbox"/> Infrastructure	<ul style="list-style-type: none"> <li>• Nutritional</li> </ul>
<input type="checkbox"/> Climate	<ul style="list-style-type: none"> <li>• Thermal</li> </ul>
<input type="checkbox"/> Environment	<ul style="list-style-type: none"> <li>• Postural</li> </ul>
	<input type="checkbox"/> Psychological-Cognitive
	<ul style="list-style-type: none"> <li>• Language and literacy</li> <li>• Stereotypes</li> </ul>

Table 4. ‘Transfer-of-technology’ and ‘people-first’ compared, adapted from Chambers et al. (57)

	Transfer of Technology	‘People first’
Main objective	Transfer technology	Empower local community
Analysis of needs and priorities by...	Outsiders	Local community assisted by outsiders
Primary R&D location	Laboratory	Workplace, fields
Transferred by	Precepts	Principles
	Messages	Methods
	Package of practices	Basket of choices
The ‘menu’	Fixed	A la carte

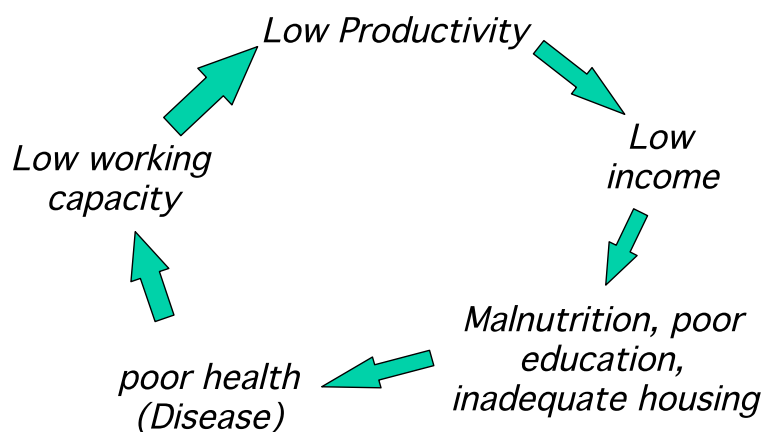


Figure 1 The so called ‘economic cycle of diseases’ (3)