# PHYSIOLOGICAL RESPONSES AND SUBJECTIVE DISCOMFORT OF SIMULATED WHOLE-BODY VIBRATION FROM A MOBILE UNDERGROUND MINING MACHINE

Thomas G. Bobick, Richard L. Unger, Sean Gallagher, and Diane M. Doyle-Coombs
U.S. Department of the Interior - Bureau of Mines
Pittsburgh Research Center, Pittsburgh, Pennsylvania

## ABSTRACT

The U.S. Bureau of Mines has developed an in-house facility to evaluate selected effects of whole-body vibration (WBV) levels experienced by underground mobile equipment operators. Vertical vibration data were collected from a coal haulage vehicle via a uniaxial accelerometer attached to the machine frame under the operator's seat. Data were analyzed and processed so a computer-controlled platform could approximate the vibration signals. Eight men (35.5 yr ± 6.5 SD) participated in a pilot study to evaluate the effects of shock and WBV on heart rate (HR), blood pressure (BP), and subjective discomfort. Subjects were exposed to vibration for 30-min periods while seated in a typical seat (backrest angle at 90° or 130°) that was plain steel or modified with 2 in foam padding. Subjects repeated the same protocol on a separate day, without the vibration. Results indicated the vibration significantly increased the HR ($p < 0.01$), systolic BP, mean BP, the number of times subjects reported discomfort, and overall subjective discomfort rating ($p < 0.05$). When seated in the steel seat, the overall discomfort rating ($p < 0.001$) and the number of times discomfort was reported ($p < 0.05$) increased significantly. Seatback angle had no significant effect on any of the dependent measures.

## INTRODUCTION

The presence of shock and vibration while operating mobile equipment is a growing concern in the underground mining industry. Minimal research has been conducted on the exposure of underground equipment operators to whole-body vibration (WBV), or on the design of appropriate seating. Many models of mobile underground equipment have seats that are only a bent steel plate. Other models may have padded seats, but the materials tend to wear out quickly in the harsh underground environment. Also, the seat is usually attached directly to the machine frame since vibration-isolation systems are difficult to install because of space limitations. Thus, the operator is subjected to almost constant vibration and shock loading during equipment operation.

A past Bureau research program (Remington, Anderson, Alakel, 1984) conducted a limited evaluation of mobile underground coal mine equipment operators to WBV. The data indicated that between 33% and 39% of the operators were exposed to vertical vibration levels that exceeded the International Standard Organization's (ISO, 1974) fatigue-decreased proficiency level (intended to preserve human working efficiency) and 7% to 14% exceeded the exposure limit (intended to protect workers from physical injury or illness caused by daily exposure at work).

Various reseach studies and reviews have indicated that WBV can affect the musculoskeletal system (Carlsoo, 1982; Seidel and Heide, 1986; Wilder, Woodworth, Frymoyer, Pope, 1982; Wilder, Frymoyer, Pope, 1985; Chaffin, Andersson, 1984), the cardiovascular system (Seidel and Heide, 1986; Wilder et al., 1982; Wilder et al., 1985), and gastrointestinal system (Seidel and Heide, 1986; Wilder et al., 1985; Kjellberg and Wikstrom, 1985). In addition to these physical and physiological effects, other studies have investigated the subjective evaluation of WBV exposure (Soule, 1973; Meister et al., 1984; Oborne and Boarer, 1982; Weaver, 1979).

The purpose of this project was to determine the effects of WBV on mobile underground mining equipment operators. Initial results of pilot subject testing are presented. Data from this research will be used to recommend changes in underground mining equipment seat design.

## METHOD

### Subjects

Eight healthy men (35.5 yr of age ± 6.5 SD) volunteered to participate in a pilot study that examined the effects of vibration, seatback angle, and presence or absence of foam padding on various physiological measures and subjective discomfort evaluations. The subjects were all employees of the Bureau of Mines Pittsburgh Research Center and were minimally familiar with the test protocol. Potential subjects were advised of the nature of the investigation and signed an informed consent form before undergoing screening medical exams. They received a thorough physical examination and graded exercise tolerance test (American College of Sports Medicine, 1980) prior to participation to ensure that they would not be adversely affected by this testing.

### Experimental Design

The independent variables in this investigation were (1) presence or absence of random, broad-band vibration, (2) seat back angle of

90° or 130°, and (3) presence or absence of foam padding material on the seat pan and back. Dependent measures included heart rate (HR), systolic, diastolic, and mean blood pressures (BP), and subjective discomfort.

The subjects were tested on two separate days--one vibrating and the other nonvibrating. During each test day, the subjects were exposed to four different seat configurations (seat back angle of 90° or 130° and padded or steel seat) for a 30-min period in each configuration. During a subject's two test days, the order of testing the four configurations was the same. However, the order of evaluating the configurations for different subjects was randomized and counterbalanced to control for bias due to the order of testing.

## Apparatus

Figure 1 presents a schematic of the equipment used in this experiment. Subjects sat in a test seat, which was equipped with an adjustable backrest, to which padding could be easily bolted. One of the configurations tested (90° seat back, no padding) was a duplicate of a typical operator's seat. The adjustable seat was mounted on a electrohydraulically powered, computer-controlled shake table. Heart rate was obtained using a Beckman1 Dynograph Recorder, Model R-511A. Blood pressures were acquired with a Narco Scientific Adult/Pediatric Non-Invasive Blood Pressure Monitor. While the subjects were seated in the various experimental conditions, they wore stereo headphones through which "pink noise" was played to mask extraneous auditory signals. The foam material was manufactured by Dynamic Systems, Inc., and was the brand designated as Pudgee. The subjects completed a subjective discomfort form three times during the test period. Figure 2 provides a schematic of the body divided into different areas on which the discomfort evaluation was based. Subjects rated their discomfort on a seven-point scale, from just noticeable (1) to moderate (4) to severe (7).

[1]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

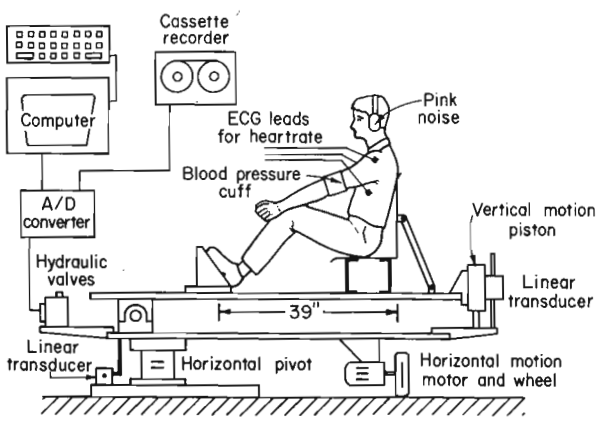


Figure 1. Schematic of vibration-generating equipment (horizontal motion not utilized).

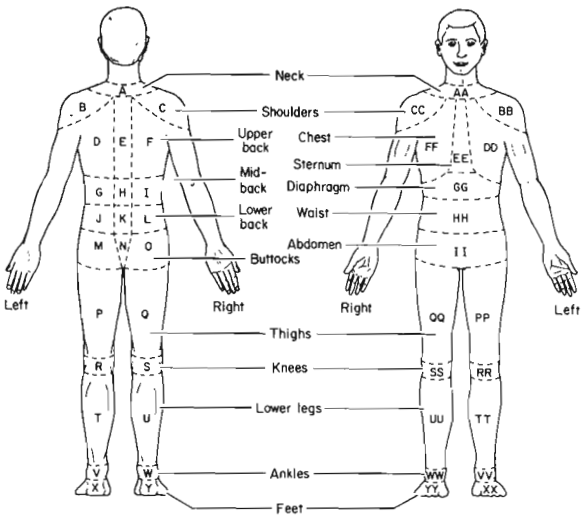


Figure 2. Body areas for the subjective discomfort evaluation.

## Experimental Task

Figure 3 provides a typical one-third-octave-band power spectrum of the vibration generated by the shake table. This spectrum is an average of the four segments of the normal cycle that the coal haulage vehicle (shuttle car) undergoes when moving coal from the mining face to the dumping point for removal to the surface. These segments are (a) loading coal into the haulage vehicle, (b) tramming loaded to the dump point, (c) unloading the coal, and (d) tramming empty back to the mining face.

Data were collected during actual shuttle car operation underground. Vertical vibration signals were collected via a uniaxial accelerometer that was attached to the machine frame directly beneath the operator's seat. These data were processed so the computer-controlled platform could approximate the signals gathered from the shuttle car during operation.

Figure 3 indicates that the composite vibration spectrum to which the subjects were exposed was broad-band and very low intensity. The acceleration levels of the spectrum were greater than 0.03 m/sec² (approximately 0.003 g) from 3.15 Hz to 80 Hz. The maximum acceleration of the vibration peaked at 10 Hz at approximately 0.3 m/sec² (approximately 0.03 g) and at 12.5 Hz at slightly less than 0.4 m/sec² (approximately 0.04 g).

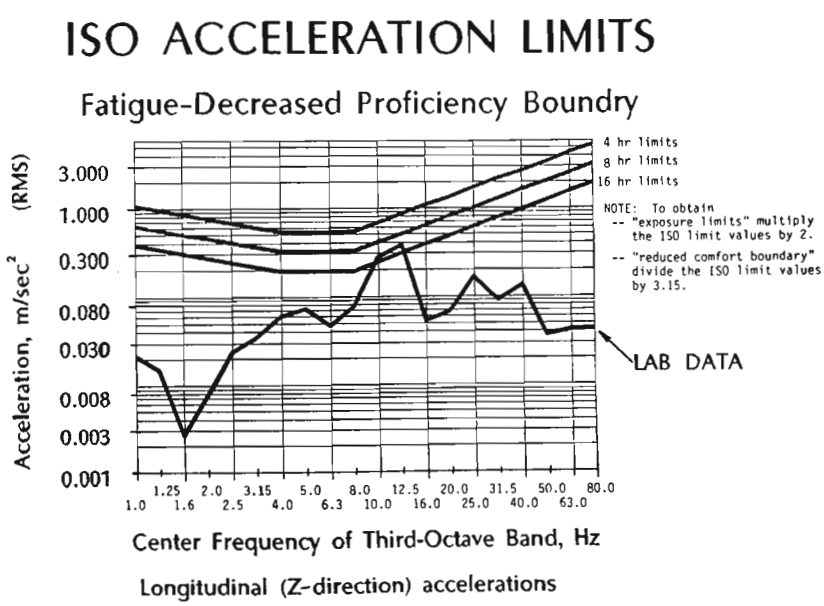


Figure 3. One-third-octave-band power spectrum of the vibration generated by the shake table compared to the ISO 2631 Fatigue-Decreased Proficiency criteria.

Prior to testing, the subject was instructed as to the experimental protocol and how to fill out the subjective discomfort form. The subject was then positioned in the seat. Before beginning the 30-min test period, each subject was instructed to sit quietly so resting heart rate and blood pressure levels could be obtained.

During testing, heart rate was collected during the last 10 sec of every min. The final 25 HR values were averaged and taken as the mean value for that test configuration. Blood pressures were collected every 5 min during programmed pauses in the vibration cycle. Systolic, diastolic, and mean values were averaged at the end of the test. Every 10 min (at min 9, 19, and 29) the subjective discomfort form was also completed. After the test period, a 30-min break was provided for the subject to attend to personal needs and to recover by relaxing in a reclined posture before beginning the next experimental condition.

Data Treatment

The results of data collected for the six dependent measures were analyzed using a 2 x 2 x 2 (vibration or not x seat back angle x seat material) analysis of variance with repeated measures (ANOVR) statistical package (Games, Gray, Herron, and Pitz, 1980). Critical alpha levels were 0.05 in all cases.

RESULTS

Physiological Data

As shown in Table 1, heart rate ($p < 0.01$), systolic BP, and mean BP ($p < 0.05$) were all significantly increased during the vibrating test day. The vibrating condition caused a 9.3% increase in the average HR (for all test configurations) over the nonvibrating conditions (69.9 to 76.4 beats per min; $F_{1,7}=14.538$, $p= 0.007$). Neither the heart rate nor the blood pressures were significantly affected by the angle of the seat back or the presence or absence of foam material. The systolic BP increased 3.2% in the average value for all test conditions from the nonvibrating day (127.1 mm Hg to 131.2 mm Hg; $F_{1,7}= 9.006$, $p= 0.020$). Additionally, the vibrating test condition caused a 4.4% increase in the mean BP for all test configurations (96.7 mm Hg to 100.9 mm Hg; $F_{1,7}= 11.052$, $p= 0.013$)

Subjective Discomfort Data

The lower portion of Table 1 presents the subjective discomfort data. The number of times the subjects reported discomfort was significantly affected by whether they were seated in the untreated (steel) seat or in the seat treated with foam padding (20.7 times for the evaluation of the steel seat versus 16.5 times for the padded seat; $F_{1,7} = 10.920$, $p = 0.013$) and also whether the subject was vibrating or

TABLE 1 -- SUMMARY OF EFFECTS FOR ALL TEST CONDITIONS

| Dependent Measures | Independent Variables | | |
|---|---|---|---|
| | Vib - No vibration | 90° - 130° | Ab - Steel |
| Heart Rate (HR) | $F_{1,7}$=14.538, p=.007 vib incr's HR | n.s. (0.580) | n.s. (0.952) |
| Systolic (sys) blood pressure (BP) | $F_{1,7}$= 9.006, p=.020 vib incr's Sys BP | n.s. (0.105) | n.s. (0.293) |
| Diastolic BP | n.s. (0.069) | n.s. (0.065) | n.s. (0.355) |
| Mean BP | $F_{1,7}$=11.052, p=.013 vib incr's Mean BP | n.s. (0.056) | n.s. (0.254) |
| No. of Subjective Discomfort Eval'ns | $F_{1,7}$= 6.927, p=.034 vib incr's number | n.s. (0.634) | $F_{1,7}$=10.920,p=.013 st incr's number |
| Overall Subjective Discomfort Rating | $F_{1,7}$=11.097, p=.013 vib incr's rating | n.s. (0.870) | $F_{1,7}$=26.989,p<.001 st incr's rating |

n.s.= nonsignificant value; vib=vibration; incr's=increases; st=steel.

not (20.8 times for the vibrating condition versus 16.4 for the nonvibrating condition; $F_{1,7}$= 6.927, p= 0.034). Similarly, the overall rating of discomfort was significantly affected by both the vibrating test condition (2.27 for the vibrating tests versus 1.76 for the nonvibrating conditions; $F_{1,7}$= 11.097, p= .013) and whether subjects were sitting in the steel seat or the treated one (2.27 for the steel seat versus 1.76 for the padded seat; $F_{1,7}$= 26.989, p < 0.001). Neither the number of times discomfort was reported nor the overall discomfort rating was significantly affected by seatback angle.

## DISCUSSION

### Physiological Data

Three of the four physiological dependent measures were significantly (p < 0.05) affected by the vibrating condition. Hasan (1970) conducted a thorough review of the literature related to the biomedical effects of whole-body vibration. He describes conflicting reports on the effects of vibration on the cardiovascular system. In general, most investigators have found no alteration in the heart rate or mean blood pressure at low frequencies of vibration. After an initial burst of activity, the HR and BP reverted back to normal or even slightly subnormal levels with continued exposure. However, a slight increase in HR and BP has been observed in subjects at a vibration frequency of 5 Hz (Hasan, 1970). The fact that the shake table generated a broad-band random signal may be the explanation for the significant increases in the heart rate and in the systolic and mean blood pressures. Diastolic blood pressure was also elevated, but was not statistically significant.

None of the four physiological measures were affected by the seat back angle, or the presence or absence of foam material. Despite the lack of statistical significance, the average values for all four physiological measurements were elevated in the 130° posture. It appears that the inclined posture caused the subjects to be more stressed, thus raising the average HR slightly (72.8 vs 73.5 beats/min) and the average blood pressure values more so (systolic: 127.9 vs 130.4 mm Hg; diastolic: 79.5 vs 82.4 mm Hg; mean: 96.9 vs 100.7 mm Hg).

### Subjective Discomfort

The last two categories of table 1 were associated with the subjective discomfort of the subjects. As expected, the number of times the subjects reported discomfort was increased significantly when they were vibrated and when seated in the steel seat. Both the vibrating condition and the steel seat significantly increased the overall rating of discomfort felt by the subjects during the testing. It is quite surprising that the seat back angle did not have any effect on either of the discomfort categories. This type of information will be valuable for the purposes of designing a favorable work station. Other seat back angles will be investigated in future research studies.

## SUMMARY OF PILOT TEST RESULTS

Results of this pilot subject testing are:

1. Heart rate and the systolic and mean blood pressures were significantly increased by the vibrating condition.

2. Both the vibrating condition and the steel seat had a significant effect on both of the subjective discomfort categories.

3. The posture of the subject (seatback angle) had no significant effect on any of the six dependent variables.

## RECOMMENDATIONS FOR FUTURE TESTING

The ultimate goal of this research project is to determine the effects of WBV on mobile underground mining equipment operators, and to develop improved seating designs for this equipment. The results of the present study have raised several points to be considered in future testing:

1. The low-seam underground environment often requires equipment to be operated while miners are lying on their backs or sides. While there were no significant effects on any of the dependent measures from the two seat back angles investigated in the present study, future research should investigate more supine postures.

2. The 30-min vibration period was chosen based on estimates of the duty cycle of underground coal haulage equipment. A longer vibration period or shorter rest period may be more appropriate to provide an accurate description of the WBV effects.

3. Any new seat configurations considered for future equipment designs will have to consider the space limitations of the operator compartments. Integrated electromyographic data will be collected to determine the activity that is occurring in the erector spinae, trapezius, or other muscles.

4. Performance tests should be included in the test protocol. A tracking task and a reaction-time test will be used to assess the effects of WBV on operating proficiency.

5. It is important to know whether mobile underground machine operators are experiencing compression of the intervertebral disks from WBV. A precise measurment of stature is needed for future research studies.

6. Back extensor muscle endurance will be measured to determine if WBV will adversely affect this variable.

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# A NEW KEYBOARD WITH CHORDED TERNARY KEYS

Karl H. E. Kroemer and Fadi A. Fathallah
Industrial Ergonomics Laboratory
Human Factors Engineering Center, IEOR Department
Virginia Tech (VPI&SU), Blacksburg, VA 24061

Lawrence W. Langley
VATELL Corporation, 2001 S. Main Street
Blacksburg, VA 24060

## ABSTRACT

A new keyboard has been used in preliminary tests. Each key has 3 state conditions ("ternary key") and is moved by horizontal displacement of the fingertip, usually together with another key (in "chords"). Little is known about the usability of such a Ternary Chord Keyboard (TCK) from previous experiments. Pilot tests indicated fast performance with a TCK.

## TCK FEATURES

Since the fall of 1987 we have been evaluating a truly new type of data input device. It consists of ternary (T) keys usually operated in chords (C) arranged on a horizontal keyboard (K). This TCK system was invented and patented by Mr. Lawrence W. Langley.

Special features of the TCK are: each key has two ON positions and one intermediate OFF position. Thus, it is a ternary key with three states, as opposed to the normal two-position (binary) key. The keys are arranged so that their activation direction is horizontal (forward/backward) instead of vertical. Finally, two or more keys are usually (although not necessarily) operated simultaneously, which is known as a chord operation.

These TCK features mean that (1) a very small number of keys represents a large number of state combinations; four keys allow eighty-one different inputs, 8 keys nearly 6,561. (2) Hence, a fingertip never needs to leave its assigned keytop. (3) This, in turn, allows to use either a wrist support, since their are no hand movements; or one can in fact "strap" the keyboard to the hand. (4) Each finger operates only one key, thus keying errors associated with activating a "wrong" key cannot occur. (5) The displacement of the key tops is only about 1 millimeter from the intermediate OFF position, hence, motoric requirements and resulting muscular fatigue are very small.

## TCK QUESTIONS

For this new TCK, questions existed which could not be answered from the literature. These included: Which designs should be applied to the keys and to their arrangement on a keyboard? Are the motoric requirements to operate the TCK keys compatible with characteristics of the human hand/arm system? What are the perceptual requirements to learn the assigned codes which associate selected key displacements with wanted outputs (characters)? What is the performance to be expected on a TCK keyboard? Are there performance transfer effects between a regular binary and the TCK keyboard?

## PRELIMINARY

### Investigations

Since the TCK keyboard posed so many new questions, a series of preliminary experiments has been performed.

First, suitable design characteristics were selected. Based on the experience of the investigators (i.e., without formal experimentation) key displacements of about 1 mm from the central OFF position at the finger interface were selected. The static force to achieve these displacements was chosen to be about 1 N. The direction of displacement was chosen to be fore-aft horizontally. The keys are arranged side by side, but at slightly different distances from the subjects frontal plane according to the natural positioning of the fingertips. The distance between centers of adjacent keys is about 22 mm. The tops of the keys protrude about 15 mm above the base surface, on which the palms of the subjects' rest. (Note that formal optimization of design features is part of the future evaluation program.) Figure 1 depicts the major design features of the 1987 keyboard.

In the first experiment, the two innermost keys of the keyboards for each hand were assigned to the index and middle fingers, respectively, of the left and right hand. (The two outer keys were not used in these experiments.) Each input was so coded that a chord of two keys was employed in each case. The numerals 0 through 9 were assigned to the chords listed in Table 1.

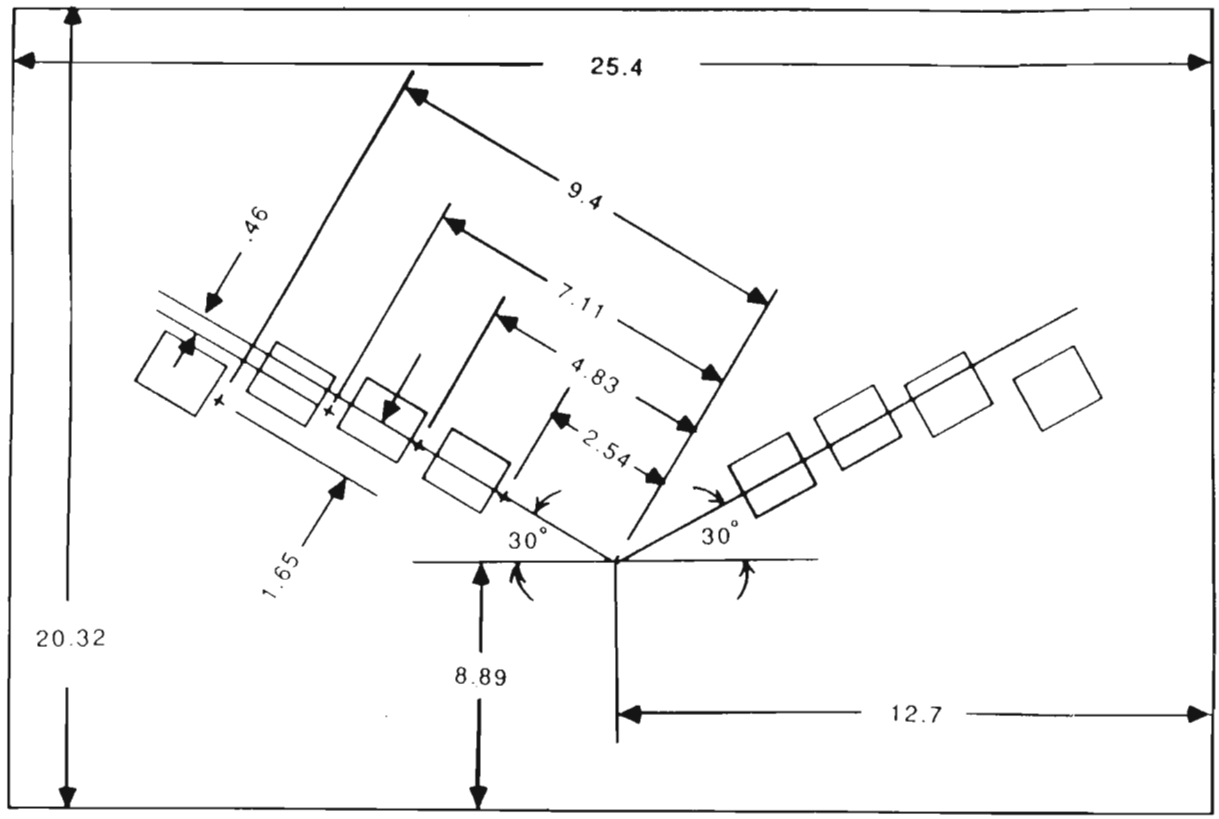


Figure 1. Location of the eight keys, four for each hand, of the 1987 TCK design. Dimensions in cm.

| Numeral | Left Middle | Left Index | Right Index | Right Middle |
|---|---|---|---|---|
| 0 | | aft | fore | |
| 1 | | fore | fore | |
| 2 | | aft | aft | |
| 3 | | fore | | fore |
| 4 | | aft | | aft |
| 5 | | fore | aft | |
| 6 | aft | | aft | |
| 7 | fore | | fore | |
| 8 | aft | | | aft |
| 9 | fore | | | fore |

Table 1: Chord Coding of the Numerals 0-9.

A training paradigm was developed in which the chords were learned in three subsets: the first consisted of the numerals 1, 2, 3, and 4. The second subset included the numerals 0 and 5. The third subset consisted of the numerals 6, 7, 8, and 9.

A software program was developed which generated, randomly, the numerals 0 through 9 and displayed these on a computer screen located directly behind the TCK. If the subject responded to the displayed target numeral by inputting the correct code, that number appeared next to the target with the word "correct," and then both were immediately replaced by a new randomly generated target numeral. Each "trial" consisted of 50 such randomly generated targets. If the subject responded to the target numeral with an incorrect code input, a beep sounded and the actually generated numeral was displayed next to the target numeral. This prompted the subject to try again to generate the correct code input.

Three subjects, one male and two female were recruited. Their participation was voluntary and no financial or other reward was offered for participation or performance.

The procedure used allowed only one subject to be present in the Industrial Ergonomics Laboratory of Virginia Tech. After providing the needed information, the first "trial" of 50 target numerals was presented. As many trials were performed as fitted into a time period of 15 minutes. The next practice session of 15 minutes took place after an intermission of at least four hours.

Two such sessions were devoted to learning inputting the numerals 0 through 4. The following two sessions were used to learn the codes for the numerals 0 and 5. A final set of two sessions was used to learn the numerals 6 through 9. Hence, each subject was trained during a total period of 1 1/2 hours to input all numerals 0 through 9.

After the six "training trials", each subject's work output was obtained during 12 "performance trials" of 15 minutes each. The outcome of the performance trials with the three subjects was measured in terms of (1) time per character input, (2) number of times the subjects needed an explanation of the correct procedure, and (3) number of errors committed per trial.

After the 1 1/2 hours of training, only in very few cases help was needed by any subject to remember the correct code. Furthermore, "errors" occurred in such few instances that their occurrence was also of no value in making any judgements about subject performance.

Though limited by the experimental conditions, and by the fact that only three subjects were trained, the results are of considerable interest. Figure 2 depicts the mean input times of subject #3. First, all subjects achieved high performance after a training of only 1.5 hours. At that point, they needed less than 1 second per input, on the average. (Note that this is a signal-reaction-response task, more complex and time consuming than common inputs to keyboards.) Second, after using all 10 numerals for less than 1 hour, in total, no further improvement in performance seemed to occur.

Altogether, the results, limited as they are by the experimental procedure, indicate that the inputting of coded numerals at high speed is quickly learned, and performed practically without errors, with the TCK.

An unexpected side result was the finding that the subjects, all of whom were used to operating regular binary keys by depressing them, showed no difficulties in learning the new method of operating keys by moving them with the fingertips fore and aft, and by employing a special code. Also, performance on the regular keyboard was not affected after using the TCK. This finding, supported by other anecdotal experiences, seems to indicate that there is no transfer of training, and no skill interference, between use of a regular keyboard and a TCK.

Recently, another set of preliminary experiments was performed with subjects selected to have minimal familiarity with keyboard use. Four of the subjects were randomly assigned to be trained on a regular keyboard, and the four other subjects were trained to use a TCK. In this case, meaningful words and sentences were constructed which consisted of various combinations of 15 inputs, i.e., 14 letters and a space.

The results of these experiments will be discussed, together with an assessment of the prospects of useful employment of the Ternary Chord Keyboard.

A listing of References will be provided upon request.

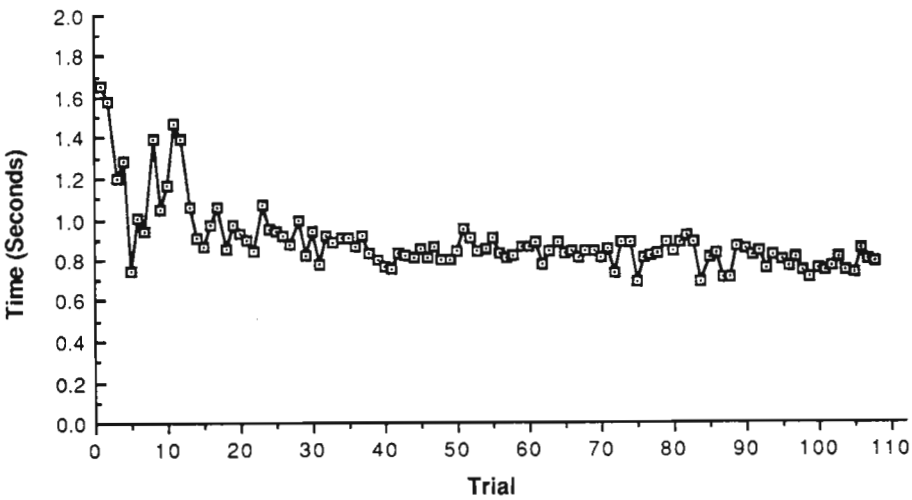


Figure 2. Mean input times for numerals 0 through 9, combined, during 108 trials, for one subject.

# PANEL SESSION ON DESIGNING SHIFT WORK SYSTEMS TO IMPROVE PERFORMANCE AND ALERTNESS: WHAT DO WE KNOW AND WHAT DO WE NEED TO KNOW?

Roger R. Rosa, Chair
National Institute for Occupational Safety and Health
Cincinnati, Ohio

Approximately 20% of tne full-time non-farm workforce in tne United States is employed on work systems using schedules other than a fixed day shift of 8 (or less) hours duration. Similar world-wide estimates have been made for industrialized countries by the International Labor Office. Work schedules grouped within these systems include permanent night snift work, rotating shift work, and regular work on shifts of greater tnan 8 hours duration. A number of factors encourage the use of these systems: many new industrial processes require continuous staffing; the number of industrialized countries is increasing; capital equipment costs can often be reduced by increasing or cnanging the hours of operation; many workers are interested in a workweek of less tnan five days; and, there has been a general increase in the demand for around-the-clock services.

Numerous studies of experienced shift workers conducted during the past ten years have shown that most night work schedules decrease sleep time, disrupt biological rhythms, and may increase fatigue. Decrements in performance and alertness associated witn night work have been demonstrated in experienced workers. Recent data suggests that increased use of extended workshifts, under compressed workweeks, may exacerbate these decrements. Such decrements may be especially apparent at night when fatigue from longer hours can summate with circadian rhythm-related declines in alertness. Although definitive workplace data is difficult to obtain, it is reasonable to argue that many 'round-the-clock shift systems significantly decrease workplace productivity and compromise worker safety and health.

Despite potential productivity, health, and safety compromises, there is little to suggest that shift workers or their management have discovered healthy and safe ways to adapt to, or cope with, their work schedules. That is, experienced shift workers still report inadequate rest and recovery, high stress, and gastrointestinal problems which are attributed to their work schedules. Presumably, optimal shift systems and individual coping methods can be devised which will minimize fatigue, promote adjustment, improve safety and health, and increase productivity. Shift system interventions are now being made with these objectives in mind. However, the appropriateness and merits of the various intervention techniques have not been publicly reviewed or discussed. This is the objective to the panel.

Each of the panel members has conducted research aimed at understanding how these intervention techniques interact with performance and recovery of function. The panelists will review what we currently know about potential shift work interventions, and attempt to identify what we need to learn if continued progress is to made toward optimal shift system designs and effective personal coping strategies. Tne individual members, dimensions, and techniques to be reviewed and discussed are as follows:

Timothy H. Monk will review 'Manipulating sleepiness by varying chronobiological napping, schedule, and performance demands'. Dr. Monk conducts biological rhythm research at the Western Psychiatric Institute of the University of Pittsburgh. He is co-editor of the book Hours of Work, and co-author of the chapter on 'Work Schedules' in the Handbook of Human Factors.

Michael H. Bonnet will review 'Physical fitness, exercise, and environmental variables as factors

influencing adjustment to shiftwork'. Dr. Bonnet is Director of the Sleep Laboratory at the Loma Linda Veterans Administration Medical Center, and a former member of the Executive committee of the Sleep Research Society.

Charmane Eastman will review 'Exposure to light as an aid or deterrent in adjusting to shift work'. Dr. Eastman is a member of the faculty in the Department of Psychology at Rush University. She directs a research program examining how light exposure timing affects the ability of shift workers to adjust to changing hours of work.

Donald I. Tepas will review variables related to the question 'Do eating and drinking habits interact with work schedule variables?'. Dr. Tepas directs the Division of Industrial & Organizational Psychology at the University of Connecticut. He co-authored the handbook chapter on 'Work Schedules' with Dr. Monk.

Richard R. Bootzin will review a broad range of 'Behavioral tecnniques for changing alertness and performance' which could be used to train individuals to optimize workplace activity. Dr. Bootzin is a Professor of Psycnology at the University of Arizona, and the author of many articles on changing sleep-wake behavior using behavioral techniques.

James K. Walsh will review the research and efficacy of 'Using psycnopharmacological aids to improve performance wnile working nights'. Dr. Walsh is Director of the Sleep Disorders Center at Deaconess Hospital in St. Louis. He is a member of the Executive Committee of the Association of Professional Sleep Societies.

James C. Duchon is a Human Factors Engineer at the U.S. Bureau of Mines Twin cities Research Center. He will serve as a discussant and conclude the panel by providing a comprehensive summary. In doing this, he will explore how these divergent intervention techniques might be used in a systems approach to shift design and workplace intervention.

Roger R. Rosa (chair) is a research psychologist with the Division of Biomedical and Behavioral Science of the National Institute for Occupational Safety and Health. He is currently directing a project examining changes in performance and alertness associated with 8-hour and 12-hour shifts, and a project on interventions for adapting to night and shift work.

# MYTH AND REALITY IN TECHNOLOGY TRANSFER: THE CLIENT-CONSULTANT RELATIONSHIP IN CONTEXT

Peter F. Beckschi
Richard E. Redding

Pacer Systems, Inc.
Horsham, Pennsylvania

ABSTRACT

Technology transfer is a process often obscured by different styles of human interaction which affect the transfer of information, skills and behaviors. Unless the human factors aspects of the client-consultant relationship are addressed, the process can result in frustrated recipients than can least afford failure, particularly in developing countries. Technology transfer is oftentimes sabotaged at an early stage without any hope of achieving project objectives. The authors contend that early model development and planning in the consultation phase will ameliorate many obstacles to transfer. A consulting model for technology transfer which incorporates systemic, cognitive, and behavioral considerations is proposed.

The western approach to the transfer of technology and expertise to developing nations has typically given precedence to the implementation of such programs, the end-products, and the empirical aspects of the process. The assumption flowing from this approach is that the prescription as formulated by the consultant is adequate for the problem. We contend that this is a myth. The reality, however, is that human factors considerations are actually more critical than those of need identification, implementation, or empirical program evaluation. Initial human factors considerations in the client-consultant relationship in the diagnostic and planning stages is critical because of the trend towards "person-embodied" consulting. In "person-embodied" consulting, the expertise of a specific individual is sought to solve a specific problem. It is necessary for the consultant to consider systemic, cognitive, and behavioral aspects of his/her relationship with the client during the early phases of the consultation.

## HISTORY OF TECHNOLOGY TRANSFER

Technology transfer became a serious concern of industrialized nations only after the Second World War with the reconstruction of devastated countries and the re-emergence of post-colonial nations. The emergence of Germany and Japan as industrial nations as well as the progress of a number of developing countries (such as the Republic of Korea and China) indicates the ability of nations to make the transition to technology despite the ravages of war or stage of socioeconomic development. Yet the record suggests that such transitions have not been as easy or as fast as some national leaders might expect (Dahlman, et al., 1985). The change from the status of a developing to industrial nation requires a number of considerations which serve as preconditions for technology transfer among which are institutional development, literacy and education, and technology selection and adaptation. Of these, the latter has become the most recent and important focus of the process of transfer.

Only recently has technology transfer become a serious topic for investigation (Dahlman, Ross-Larson, and Westphal, 1985). Studies in the selection and adaptation of technology are still incomplete despite a number of case histories developed by international organizations such as the United Nations Development Program and the World Bank (see Dahlman, et al., 1985; Lethem and Cooper, 1983). Anecdotal information often serves as a valuable substitute for the lack of empirical data. The state of technology transfer, therefore, can benefit from research in the areas of human factors, training, managerial science, and psychology.

### Role of Technical Assistance

The selection and adaptation of technology for transfer is usually effected through international technical assistance programs. Unfortunately, instead of leading to further development and becoming a means for better international understanding, many of these programs have become wasteful of resources as well as potential and actual sources of international embarrassment and frustration.

At the core of technical assistance is the relationship between the consultant (the technical assistance or "change" agent) and the recipient. These relationships are usually specified in terms of specific services, technologies, or information to be provided. Goulet (1975) identifies such relationships as either product-embodied technology, process-embodied technology, or person-embodied technology. One or all of these modes may be employed to produce the desired result in technical assistance.

Product-embodied technology is highly sophisticated. It represents a unique way in which a product is produced or assembled. The level of expertise is highly dependent on the skills possessed within a firm or organization.

The generalization, for instance, that automobile manufacturers have similar skills and products is inadequate when consumers react more favorably to a preferred product such as Japanese automobiles. Process-embodied technology, less sophisticated than product-embodied technology, requires the application of specific processes to indigenous material and human resources such as petrochemicals, food production and manufacturing enterprises. Person-embodied technology involves the explicit transfer of information to solve some specific current or potential problem. In this case, it is the knowledge and experience of the individual consultants which is sought. Person-embodied technology may also become an integral part of product- or process-embodied technology.

Inherent within these three types of technology transfer are different levels of intensity which guide the client-consultant relationship. Historically, major technical assistance programs have been structured around process-embodied technology in order to establish an industrial or agricultural knowledge base in developing countries. Although the need for process-embodied technology still exists in certain countries, the trend has shifted to other types, which require more sophisticated consulting skills. This trend is due in large measure to two developments over the past two decades--the widespread availability of process-embodied technology and the development of an indigenous class of consultants (Casino, 1983). The worldwide glut of cement, petroleum, and similar basic materials underscores the capabilities of many developing countries to master their own resources. Thus, process-embodied technology transfer is no longer needed in many developing countries. Many plants in such countries no longer exclusively rely on outside resident consultants or workers to maintain production. The recognized need in many of these countries is to better rationalize production capabilities through innovations to increase productivity and efficiency in managing resources.

The emphasis for the consultant, then, has shifted to the product-embodied and person-embodied technologies and the requirements for successful technology transfer depend more than ever upon the skills of the consultant and client. The consultant-client interface (CCI) should be the primary focus for development programs.

## CONSULTING AS PROCESS

A number of models have been proposed (see Lethem and Cooper, 1983) for effecting technical assistance based on a systems approach. Such models have proven useful in examining the different categories of processes which interact or represent recognizable stages of evolution in technical assistance. The literature suggests a number of consulting process models which are comparable to the technical assistance model. Experience of the authors indicates that no single model adequately fits every situation or project. Models do serve as useful guides in establishing more precise definitions of the complex processes in technology transfer, and more specifically the CCI.

In this regard, the process-embodied approach fits the typical cycle of project management with an emphasis on the design of activities, administration, and implementation. So-called "turnkey projects," for instance, which are methods for transferring process technology, have met with various degrees of success depending upon the degree of influence of the CCI. Some nations have been able to eliminate the need for extensive CCI. The Republic of Korea, for instance, has minimized the need for CCI by simply importing a plant, and then performing "reverse engineering" and subsequent adaptations without requiring extensive consultation before, during, or after the project. Such "black box turnkey projects" do not develop local technological capacity without the information and understanding of how and why the process works. "Black boxes" tend to serve the interests of the equipment suppliers and consultants rather than the recipient. The turnkey project is limited to certain environments where preconditions exist for the acquisition of relevant skills without interventions of consultants. What is apparent from an examination of projects which require such consultations is that the establishment of the CCI has been minimized in favor of the empirical aspects of design, implementation, and program evaluation.

Other approaches, however, focus upon the consulting process. Recent research on improving the client-consultant interface indicates that three processes are pivotal to the success of the consulting process: the matching process, the contracting process, and the communication process (Kellogg, 1987). Lethem and Cooper (1983) identify similar human factors considerations which, in contrast to physical investments, "do not seem to generate momentum toward implementation." The critical area is the "matching process" which emphasizes the personalities, skills, needs, and goals of the CCI. These considerations are rarely incorporated into current contracting efforts which rely more upon "black box" project models. Such models separate the establishment of the CCI as well as the diagnostic phase of the consulting from the more empirically definable design and implementation phases. Disjoining the process in this manner can invite failure since person-embodied technology, and to a lesser extent product-embodied technology, must rely more heavily upon the client-consultant relationship which necessarily precedes design and implementation.

Within either the process-embodied model or the consulting model (see Figure 1), such discontinuities will most likely occur just prior

to or after the design of services. For the consultant, the terms of reference (TOR) is the primary document guiding implementation of the project. Once prepared, however, the TOR is rarely followed through to completion by the implementors of the project thereby interrupting continuity of the project at a very vulnerable stage. The subsequent breakup of the "ownership" of the goals and roles throughout the consultation process results in diminished CCI.

Figure 1: COMPARISON OF PROCESS-EMBODIED AND CONSULTING MODELS

| Technical Assistance Process Model [a] | Consulting Model [b] |
|---|---|
| I) Identify need | Establishment of CCI |
| II) Examine feasibility | Diagnosis and prognosis<br>Development of appropriate mental models |
| III) Design of services | Design of services<br>Consensus on terms of reference |
| IV) Administration and implementation | Commitment and implementation |
| V) Termination | Termination/renewal |

[a] Based upon model provided by Lethem and Cooper (1983).
[b] Based upon experience of the authors as well as other models.

## Roles of Client and Consultant

A technical assistance program should be perceived as an exchange defined not simply by the contractual terms but, more importantly, by the psychosocial aspects of the situation impinging upon the project. If divorced from the initial CCI or perhaps even the design of the TOR, the consultant will not participate in the process of identification of shared goals. The client-consultant relationship should be an integral part of any diagnosis-prescription and subsequent consulting activities. At the end of the consulting assignment the client expects (and is expected, by involved lenders!) to possess and control the use of the new technologies and skills. Without early involvement, the CCI will most likely not be able to agree upon a psychologically equitable contract. Roles will not have been defined until later stages. Both the consultant and client can easily find themselves engaged in a mechanistic and unsatisfactory relationship that merely meets the requirements of bureaucratic standards but which does not achieve authentic communication.

The diversity and complexity of technology transfer, however, requires a more comprehensive approach in most cases, necessitating numerous consultants often from more than one organization. A consultant team is often needed which includes expatriate and indigenous consultants working together. Otherwise, the expatriate consultant may find himself/herself only able to provide diagnosis and prescription advice without following through with implementation. This, in turn, can be quite damaging to the client. In one case, a chemical specialist assisted a firm in a host country only to advise that inferior materials were the cause of a below-standard finished product. Years later it was discovered under another assistance contract that substitute materials could be found in adequate quantities in an adjoining governmental district within the same country.

Collecting the necessary empirical and cultural data to effect technological transfer requires certain behavioral and cognitive skills on the part of the consultant to deal with the problem in its totality. If additional consultants are required, they should be under the direction of the original consultant who maintains contact with the client throughout the process. Change is a difficult process for most clients who quite naturally may react defensively to some suggestions from new consultants and then begin to seek solutions at random.

Thus, the voluntary nature of the client-consultant relationship cannot be overemphasized. The client should be made aware that he/she is free to terminate the consulting relationship at any time and seek solutions appropriate to conditions. This is less likely to occur when the CCI is established early. Defense reduction occurs only as the relationship evolves. A major educational institution in the Far East was unable to implement needed reforms until the consultant gained the confidence of the faculty over a long period of time, and reduced any perceived threat to their seniority. Prior contacts through administrative officers proved inadequate since the scope and intent of the changes were not adequately communicated to faculty members by previous consultants who were constrained by time limitations.

Personality and Behavioral Traits

Beyond expertise in a specific area, the consultant must have developed an awareness that extends beyond perfunctory intercultural skills. For example, the Swedish Ministry of Foreign Affairs reportedly has identified personality criteria desirable of staff sent abroad (Lethem and Cooper, 1983). Included among the characteristics are social judgment, adaptability, initiative, patience, perseverance, and talents for administration and teaching. The study also included data from a Canadian survey which implied that personal qualities contributing to job success in industrialized nations may not be the most useful ones for working in developing nations.

Often consultants from industrialized countries have fixed notions of what a client needs based upon superficial contact or prescribed terms of reference. This appears to be particularly true for consultants in empirical professions such as engineering and accounting. Unless consultants can expand their repertoire of skills and adapt to expressed client needs, the chances for successful technology transfer are greatly diminished. Teaming of skills among specialized consultants can help overcome this barrier.

## THE CLIENT-CONSULTANT RELATIONSHIP IN CONTEXT: COGNITIVE AND SYSTEMS APPROACHES TO CONSULTING

We have argued for a cognitive as well as systemic approach to the process of technology transfer, specifically as related to the client-consultant relationship. The systems approach to social problems is one which gives equal emphasis to individuals as well as to the overall social structure or system. The cognitive approach emphasizes the role of individuals' capabilities, expectations, and perceptions in guiding human interactions. We contend that one or both of these approaches is often excluded in the process of technology transfer. Both views, however, have important implications for the CCI in technology transfer, and both are readily integrated into a cognitive-systems framework.

General systems theories (i.e., Boulding, 1956; Sameroff, 1983) offer a holistic and ecological view of human interactions. An understanding of the overall system and its interrelationships is considered a prerequisite to understanding specific relationships within that system. In practical terms, then, the consultant needs a good understanding of the overall mission(s) of the organizations involved as well as of the institution in relation to the client and consultant. Critical is an appreciation for the context in which the consulting occurs. The systems perspective is one which assumes that when any aspect of a system changes every other aspect of that system changes also. No one factor, therefore, can be considered in isolation within the consultation process. The client-consultant relationship should not be viewed as client versus consultant but, rather, as client and consultant working reciprocally within a larger context.

Cognitive psychology is concerned with mental operations and processes which guide human behavior, such as intelligence, decision-making, problem-solving styles, prior expectations, and so forth (see Bobrow and Collins, 1975; Gentner and Stevens, 1983). Central to this approach is the concept of the "mental model" or "schema." Mental models are evolving abstractions stored in memory about a generic domain or task (nuclear physics, or operating a boiler plant for instance) which guide a person's approach to specific problems or situations.

Researchers have found that the majority of errors in problem-solving occur prior to actually attempting the solution and can be traced to faulty mental models (Rumelhart and Norman, 1981). Similarly, we contend that the majority of problems within the CCI relationship are due to faulty mental models (and the preconceptions and expectations which are derived from such models) of either the client or consultant, or a mismatch between the two. The client and consultant often have faulty or conflicting expectations and perceptions regarding the nature of the problem, the institutions, the end-product, or perhaps even the nature of the mission itself. The consultant may characterize the problem area (or even the entire field or mission) in one manner while the client may view it in a disparate way. Development of appropriate mental models for the task and situation, particularly on the part of the consultant, needs to take place early on in the consulting process.

Mental models for various domains of knowledge and skills have also been found to generally differ between novices, experts, and persons who possess intermediate levels of expertise. They are organized differently, with different concepts delegated to different levels of importance. Expert mental models are also more hierarchical, more highly and tightly elaborated, easier to access and apply, less context-specific, and more automated (Bransford, Sherwood, Vye, and Reiser, 1986; Ryder, Redding, and Beckschi, 1987). Typically, the client is the novice who is seeking expertise from the consultant, who is presumably (but not always!) the expert. This discrepancy in itself can often be a source for conflict and misunderstanding as the client and consultant may have different mental models and perceptions about the problem at hand and how to solve it. Transferring nuclear technology to nations with little experience or understanding of such technology is problematic since the lack of experience often leads to faulty preconceptions by the client. Similarly, the consultant's expectations about capabilities of the client and his or her environment can lead to frustration when such expectations fall short of reality.

## CONCLUSION

The western approach to technology transfer has typically emphasized the empirical aspects of the process such as design, implementation, and program evaluation, rather than the dynamics of the client-consultant relationship. In contrast, what are the implications of the cognitive-systemic approach to consulting for the process of technology transfer? Firstly, human factors considerations, particularly relating to the client-consultant relationship, are of paramount importance. This approach addresses the role of the consultant in relationship to the needs of the client, emphasizes the establishment of the CCI, development of appropriate mental models, consensus on the contractual terms of reference, and the renewal of short term contracts (see Figure 1). The CCI needs to be established as early and comprehensively as possible in the consulting process. The consultant needs to consider the overall environment and context in which he performs the consulting mission and how this affects his/her relationship with the client. What are the missions of the institutions involved? What are the capabilities, expectations, perceptions and biases of the client and how are these affected by the institutions? What is the client's overall conceptualization of the task and problem and how might this change over time as technology and expertise is transferred to the client? All of these factors need to be considered simultaneously.

It would be naive to envisage significant change in the existing structure of technology transfer in the near future. One area which is amenable to immediate change is for developing countries to assume greater organizational responsibility for their technological development. Insofar as is possible, the contracting of long-term resident consultants should be avoided. Instead, short-term, renewable contracts are beneficial to the client-consultant relationship. Arranging for consultants to provide expertise on short-term visits would provide the autonomy and openness that is necessary for creativity, appropriate perspective-taking, and genuine assistance (rather than pseudo-colonialism). Concomitant with the arrangement for short-term consultants is the need to train specialists to act as consultants in a cross-cultural setting or to train an indigenous core of consultants (Kofler and Meshkati, 1987).

Finally, additional research is needed to support a more comprehensive working model for the CCI, a model which addresses human factors issues in the process of technology transfer.

## FOOTNOTE

Unless otherwise indicated, examples of cross-cultural consultation and technology transfer are derived from the experience of the authors and their associates in these areas.

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# DEFICIENCIES OF ANTHROPOMETRICAL AND OSTEOMETRICAL DATA BASES FOR TECHNOLOGY TRANSFER WORK

Rose Oldfield Hayes, Ph.D.

US Postal Service Headquarters
Washington D.C.

ABSTRACT

Anthropometrical and osteometrical data bases have deficiencies which, when used without consulting an experienced physical anthropologist, skeletal biologist or anatomist, result in poor designs for technology transfer, place target populations at high risk and/or constrain projected productivity. These deficiencies are due to technical inadequacy, sampling and non-sampling error, population differences, differential maturation, ethnic variation, universal growth, environmental influences and gender differences. The development of a perpetual computer-based universal data bank is recommended for international technology transfer work, as well as for medical research and practice, industrial design, government programs and military requirements.

## INTRODUCTION

Technology transfer work, whether national or international, involves transmitting ideas and/or materials from one context to another. There are a multitude of variables related to the success of nonsuccess of such transfer efforts, particularly when the transfer is from one national context to another national context.

Cultural and social variables such as language and cognition systems, sex roles, child rearing practices, religious beliefs and practices, and even kinship systems can obstruct the succesful implementation of a foreign technology. Developmental literature abounds with failure stories of programs and projects which ignored such variables and became inextricably mired down in a swamp of sociocultural quicksand that fatally complicated program goals and objectives.

Equally related to the success of transferred technologies is the relationship between the physical characteristics of the transferred technologies and the biological characteristics of the target population. Deficiencies in these areas can cause accidents, injuries, and illnesses. Projected productivity levels are especially compromised by such deficiencies.

Human anthropometrical and osteometrical characteristics are extremely complex, imperfectly understood by the scientists who specialize in these fields, and poorly documented. Generally speaking, during the past four million years of evolution the size of the human species has become increasingly larger and the morphology of the widely dispersed groups has become increasingly diversified.

The early Australopithecines stood about 4 feet high and had small brain cases which measured about 450 cubic centimeters. The "average" man of modern western countries is about 5'9" tall with a brain case of approximately 1,450 cubic centimeters. The diversity which has characterized human physical evolution has involved striking differences between groups. There are also differences among groups, and even differences within any one individual.

For more than a century, physical anthropology has collected a bewildering and global variety of data describing human beings and their skeletal remains. Physical anthropologists, some skeletal biologists and some anatomists have specialized in modern human anthropometry and osteology, compiling enormous compendiums of data on human physical characteristics and their variations. These data have been reported in all scholarly languages, publications and professional journals. It is possible to get computer printouts, hundreds of pages in length, listing anthropometrical and osteological publications. However, this apparent abundance merely serves to underline the extent to which poor work designs can be achieved by planners who naively use this data.

Most Human Factors Specialists, Human Factors Engineers or Ergonomists lack the training and research background required to properly develop or reliably evaluate and utilize existing anthropometrical and osteometrical data bases. In order to emphasize the critical need for consulting with appropriate experts during the design and implementation stages of programs and projects aimed at the successful transfer of technology between international populations this paper discusses and explains the deficiencies of such data bases. These deficiencies are discussed in terms of technical inadequacy, sampling and non-sampling error, population differences, differential maturation, ethnic variation, universal growth, environmental influence on growth, and gender differences.

## TECHNICAL INADEQUACY

Anthropometry is the study and comparison of human body measurements. Osteology is the measurement and comparison of defleshed bone. While the term anthropometry is usually used in Human Factors work to encompass both areas there is a distinct and important difference in the two areas since flesh and fat distribution will vary between and among members of a population and/or gender. In medico/safety applications the degree of specificity required often excludes the generalities necessary in the use of anthropometric data and necessitates the use of osteometric data. Such data is available from both skeletal and living populations. Osteometrical data on living populations can, of course, be obtained through analysis of roentgenographs/radiographs.

Specialized equipment which has been developed for measuring human bone size and body form include, but is not limited to, the anthropometer, the sliding caliper, the spreading caliper, and the osteometric board. These precision instruments are functionally shaped and calibrated in millimeters and centimeters. The goniometer has also been developed for use in precisely measuring bone and body angles. Other instruments should not be substituted in anthropometrical or osteometrical studies.

Technical inadequacy occurs when anthropometrical or osteolometrical studies are conducted without utilizing proper techniques, equipment and anatomical reference points. When anthropometrical and osteometrical studies are conducted by trained and experienced experts, using the highly precise equipment developed for such studies, along with the statistical techniques developed for organizing and explaining the data, the information collected is objective, quantifiable, verifiable and comparable. It therefore allows conclusions to be arrived at which have a high degree of scientific certainty.

## SAMPLING AND NON-SAMPLING ERROR

Normally, we cannot measure, or know the mean and standard deviation of an entire population, especially in international technology transfer work. Very little anthropometrical and osteometrical data on Third World populations exists. It is therefore necessary to study a randomly selected sample group which should be representative of the target population. The extent to which the sample group is representative of the entire population is expressed through a statement of the mean and standard deviations. Sampling error results from non-random selection of representatives of the population.

Non-sampling error can also occur from mistakes and inaccuuracies in observation, as when representatives of a population are measured by untrained practitioners. For example, when Krogman (1971) was annotating articles on child growth for the publication, Growth of Man, he "threw out nearly one-half of the studies for inadequacies of sample size, poor statistical analysis, and sloppy definition of measurements so that comparability was poor or non-existent".

## POPULATION DIFFERENCES

Anthropometrical and osteometrical studies organize the resultant data into categories which describe the physical characteristics of a certain percentile of the subject population. For example, stature may be given for the 5th, 50th and 95th percentiles of the population.

Unfortunately, under application conditions, such studies are usually gross generalities of the anthropometrics and osteometrics of actual individual workers. This is because, as indicated above, there is a large variability of unknown proportions between populations, among members of a population, and within any one individual.

On the individual level, a person may be a particular percentile in stature but would be categorized as a different percentile where leg length, shoulder breadth, waist circumference, seated eye level, etc., is concerned. For most (but not all) individuals, there are 206 long, short and irregular bones in the body which grow and articulate according to processes that are determined by complex genetic and environmental factors. No one individual is exactly described by the measurements of another.

On the group level, Bittner et al. (1975) effectively demonstrated this restriction using a computer technique call Monte Carlo Modeling. This technique demonstrates the "problems of categories" by studying the degree of error that can occur in using a specified percentile throughout the design of a workplace. They found that if a policy of accommodating 95 percent of the population (i.e., excluding 5 percent) is vigorously followed through seven sets of anthropometric constraints (e.g. stature, seated eye level height, popliteal height, etc.), 25 percent of the population is actually excluded. This cumulative effect through filtering occurs because each successive dimension excludes 5 percent of users and since the dimenssions are not perfectly correlated, a different 5 percent are excluded each time.

Therefore, the characteristics of the 5th, 50th, or 95th percentiles from one population may imperfectly describe the characteristics of individuals in those same percentiles in

another population. Such differences can lead to serious error in technology designs for the unwary data base user.

## DIFFERENTIAL MATURATION

Cameron et al. (1982) conducted research which indicates that the adolescent spurt of growth effects the different parts of the body at varying rates. In terms of growth and body change, Tanner (1962) pointed out that the upper parts of the body, especially the head, are closer to their eventual adult size than the lower parts. The upper limbs are further developed than the lower, and the distal areas are further developed than the proximal areas. It follows, then, that the range of variations in peoples' anthropometrical and osteometrical characteristics will not remain consistent throughout their growth. It therefore becomes important to know and control for the age range of a population which is being designed for.

## ETHNIC VARIATION

Ethnic variations will have extensive impacts on design requirements for international technology transfer work. The so-called caucasoid, mongoloid and negroid races differ in morphological characteristics in such a way that those of us involved in forensic anthropology work can often identify the "race" of certain skeletal material with a high degree of accuracy. These differences are particularly pronounced in the formation of the maxillary, nasal and femur bones, in the relative proportion of long bone length to stature, and in dentition development (Ubelaker,1978:44). Other cranial and post-cranial differences exist, as well.

For instance, black Africans have proportionally longer lower limbs than Europeans. Far Eastern peoples have proportionally shorter limbs, with the Japanese having the shortest, the Chinese and Koreans having the next shortest, and the Thai and Vietnamese having the least shortest (Pheasant, 1986:50).

Trotter and Gleser (1952:495) report different osteometric regression equations for estimating the stature of Whites, Negroes, Mongoloids and Mexicans, as follows:

| | |
|---|---|
| WHITES | Stature = 2.32 Femur + 65.53 $\pm$ 3.94 |
| NEGROES | Stature = 2.10 Femur + 72.22 $\pm$ 3.91 |
| MONGOLOID | Stature = 2.15 Femur + 72.57 $\pm$ 3.80 |
| MEXICAN | Stature = 2.44 Femur + 58.67 $\pm$ 2.99 |

As Pheasant (ibid.) indicates, anthropometric percentiles are specific to the population which they describe. Therefore, data on one group cannot be used in technology transfer efforts for a different group. To do so is to introduce a margin of error which renders the data or design undependable, even potentially dangerous where human health, safety and productivity are concerned.

## UNIVERSAL GROWTH

Universal growth causes dated anthropometrical and osteometrical data bases to become anachronistic due to a secular trend in the homo sapiens species toward increased size.

Tanner (1978) summarized the available evidence and concluded that populations of Europe, the United States, Canada and Australia increased in stature by about 15 mm per decade between 1880 and 1960. Therefore, even the reliability of scientifically sound anthropometrical and osteometrical data is reduced in direct proportion to the age of the data base. Practitioners must therefore control for the age of the data bases which they use.

This is an area where non-expert applicators often err. For instance, the Anthropometric Source Book (1978) is currently in wide use as a guide to human dimensions since it contains multi-national data. However, Kleeman (1987) reviewed anthropometrical data bases in order to make recommendations for dimensioning video display terminal workstations and noted that, while useful, the drawbacks of this data base include small sample size and dated material in many sections.

## ENVIRONMENTAL INFLUENCES

Environmental influences apparently influence many human physical characteristics, such as skin color, hair formation and stature.

Environmental influences on growth also appear to result in marked intergenerational differences in anthropometrics and osteometrics where immigration is involved.

For example, Shapiro (1939) found that first generation Hawaiian-born Japanese were taller than their immigrant progenitors and larger in most other dimensions. Such environmentally determined changes effectively result in new, distinct groups to which existing data bases do not apply.

## GENDER DIFFERENCES

Gender differences are significant enough that measurements for one sex are inappropriate for members of the opposite sex (same percentile).

Using measurements from the roentgenograms of 67 subjects, Anderson et al. (1964:198) found that at age 18 males had a mean femur length of 47.23 cm. The mean female femur length for age 18 years was 43.63 cm.

Stoudt et al. (1965) reported on the adult civilian population of the USA. Their data showed that in general, men exceed women in all the linear bodily dimensions except hip breadth. The lengths of the upper and lower limbs and their component parts are proportionally and absolutely longer for men. However, the buttock-knee length is proportionally greater in women. This is because anthropometry takes into account the fleshier buttock of women. If osteometrical measurements were used, this difference would be modified to relect defleshed bone. This study also reports that the mean stature for adult civilian U.S. men is 1732 mm while the mean stature for females is 1600 mm. These values, when corrected by 15 mm per decade, as Shapiro (ibid.) recommends,would indicate that the average male stature is approximately 69.3 inches and the average female stature is approximately 64.2 inches.

## CONCLUSIONS

The differences in anthropometrical and osteometrical measurements between groups, among group members and within any one individual must be controlled for and incorporated into technology designs and transfers inorder to protect worker safety and health, and projected performance levels. This is particularly true when the technology designs are being transferred from one national context to another. As demonstrated above, inter-group/inter-individual differences are marked and exist as pitfalls for the unwary Human Factors Specialist.

Even when trained experts in anthropometrical and osteometrical data bases are consulted, they are often at a disadvantage for providing specific measurements. Where they cannot provide specific measurements, however, they can provide appropriate data adjustments and statistical probabilities concerning the appropriateness of the data or data range.

Needless to say, it would be to everyone's benefit if such experts had reliable current data bases to work from. A universal, perpetual and computer-based data bank housing current and reliable data on human body measurements should be developed. Such data would not only be invaluable in international technology transfer work, but would also provide critical information to governments, military organizations, manufacturing and service industries, medical researchers and others. The original cost would be extremely high but could be offset by subscriber fees. Subscriber fees and data sales could be used to maintain and update the data base.

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# A COMPARISON OF THE RELIGIOUS AND CULTURAL ROOTS OF MANAGEMENT PRACTICES IN FOUR NATIONS

Paul R. McCright and R. Venkatesh
Dept. of Industrial Engineering
Kansas State University, Manhattan, KS 66506

## ABSTRACT

The behavior and motivation of business managers are influenced by the values of the surrounding culture. The norms of the social and cultural system are influenced by the behavior and requirements of the business. The purpose of this study is to present one view of why management practices in other countries are different from those in the United States. The general thesis of this study is that management practices in any nation's culture are deeply rooted in the historical and religious origins of that nation's culture. Literature covering management practices and national cultures is reviewed. This study shows that any change in management practices should give careful consideration to the existing culture.

## INTRODUCTION

The principle objective of a business organization is to produce goods or services in exchange for payment. Any business enterprise is a social organization operating in a social environment. Society exploits the business to obtain the production of goods and services while granting the business some degree of license to exploit society for its own ends. Management tasks, then, are social as well as economic and technological in nature, and are inescapably fashioned to fit the social and cultural environment of the business. The interchange between business and its environment is, however, not a one way street. The behavior and motivation of business managers are influenced by values of the surrounding culture. The norms of the social and cultural system are influenced by the behavior and requirements of the business community. This mutual influence becomes even more complicated when an organization seeks to do business in a culture different from its own.

Negandhi (1975) wrote that management practices, behavior, and effectiveness are functions of technology, location, market conditions and socio-cultural variables. Bedian (1975) stated that different cultures possess different organizational norms and behavior standards. Management practices of any nation are deeply rooted in the historical and religious origins of that nation's culture. They are a product of customs and traditional social values and are also closely related to the existing social and economic system.

Flynn (1982) states that the influence of business on the culture and customs of the country is noticeably strong in Japan and the United States, which are fully industrialized. Harari and Zeira (1977) write that there is a similarity of perception among employees in industrialized countries, irrespective of organization behavior and corporate structure. The general populace is aware that the welfare of all individuals is affected by gross national product or lack thereof. This is not true in the cases of India and Egypt, where a major portion of the people are illiterate and live in poverty areas. Consequently, the influence of business practices on social customs and culture is largely confined to major cities.

In time every organization develops a life and culture peculiarly its own. Certain basic attitudes about the people of the organization and their work slowly become entrenched and accepted. In a business organization these attitudes exert decisive influence in a wide range of critical areas such as production methods, job skills, discipline and morale, and management decision making. Attitudes within the organization are derived from the attitudes prevailing in the culture from which the organization members are recruited. Management practices, therefore must cope with the attitudes and prejudices of the cultures constituting the organization. Since these cultures have been influenced by religious doctrine and history, some do not contribute to the efficiency and productivity of business enterprises.

Social values and ideologies are a result of evolutionary change over a considerable length of time. Moreover, the present cultural environment is a product of the intermingling of many cultures. Long and Seo (1977) believe this can lead to contradictory values even within the same society. They also state that business customs have their roots in the precepts of religion.

In order to examine the relationship between the religious origins of culture, cultural values, and management practices, four nations are compared. These nations represent four of the major religions practiced in the world. They are the United States (Judeo-Christian), Japan (Buddhism), India (Hinduism), and Egypt (Islam).

## JAPAN

### Historical Perspective

A system of Japanese management existed during the feudal 'Tokugawa' era during the years 1600 to 1868. Japan's mountainous nature gave rise to a village based population with strong loyalties to local heirarchies. This indigenous Japanese culture was influenced over time by periodic visits of Buddhist missionaries. The result was codification of certain philosophical traditions based on Confucianism. The Confucian tradition valued external order and harmony within society, while emphasizing the collective aspect of the social order. This point is extremely important in understanding the root philosophical foundation of Japanese management: the rejection of Western individualism. (Craig and Fairbank 1973)

Yoshino (1968) identified a set of values which came to form the social order of society. During the 'Tokugawa' period, the Samurai were considered inherently superior. They were warriors, loyal to their feudal leaders. With the abolition of the feudal system during the Meijo restoration (1868), these values were transferred to the managerial class. Thus their own professional development became synonymous with the development of the firm. They were rewarded for this dedication by a system of benefits which set them apart from others in society. Ultimately, society accepted the notion of heirarchy as long as the elitism justified itself through legitimate behavior. The specifics of the Japanese management system flow from these historical roots.

### Management Structures

The industrialization of Japan is rooted in enabling religious doctrine and the resulting familial system in which the entire nation is considered to be one huge family. The emergence of the 'zaibatsu' (large corporate entities controlled by a select few of the wealthiest families) in the late nineteenth century was a logical adaptation of the familial system to the task of industrialization. (Sours 1982)

The Japanese management system is a product of Japan's unique culture. Japanese managers do not behave as individuals, but as members of groups. A manager is the leader of a group and a subgroup below. All members move as an entity without deviation from the group. This is an absolute requirement in Japanese organizations. Hattori (1977) describes this as a conformation-authoritization process of decision making. One of the paths to being successful in an organization is loyalty. In decision making processes, group consciousness functions more prominently. No individual member can make decisions by himself. Drucker (1971) calls it decision making by consensus. Vogel (1979) views the process as root binding that leads to the high level of commitment necessary for the implementation of decision making at the lower echelons of the organization.

Japanese management cannot be readily separated into top, middle, and lower levels of management. The Japanese enterprise must be regarded as a whole organism. Operational units, whether they be sections or departments, are expected to contribute some specific portion of the whole performance not as separate entities, but as a part of the whole. (Keesling 1982) In this manner, each operational unit loses accountability for its performance. Consequently the concepts of authority and responsibility are quite different from those in the West. The fundamental basis of organization is not authority, but harmony. Harmony is achieved by the delicate balance between units maintained by their identification with the whole. (Ballon 1969)

Chang (1982) states that in Japan individualistic attitudes take on distasteful connotations of egoism and arrogance. Nevertheless, aspiration for excellence and individual glory is a common phenomenon in Japan. The concept of promotion is a good example. In a society where seniority is dominant, promotion is limited to an extent. The aspiration for promotion elicits fierce (often covert) competition within the same organization. If one desires to be promoted, he must show his loyalty to his superiors. Thus individualism does exist, but cannot be pursued openly.

## EGYPT

### Historical Perspective

Egypt is one of the oldest civilizations on earth, pre-dating the dawn of historical records. Thus it has a culture which has been developed over centuries.

Throughout its long development, the Nile Valley has received numerous accretions of people, each bringing variant cultural contributions. Some contributions of alien cultures were assimilated; however, most were shed as the Egyptian civilization solidified. The Persian conquest of 525 B.C. brought the influence of a civilization as complex as the existing one. (Berque 1972). Later came Greeks, Romans, Byzantines, Arabs, Turks and Albanians. The nineteenth century saw the stretching of the French and British empires into North Africa. In 1798, Napoleon conquered Egypt. Although an Egyptian government remained, real power passed to the French. As time passed, the British became more involved in Egyptian politics as well. In 1879, the Europeans overthrew the Egyptian Viceroy and inaugurated a period of colonization which lasted through World War I. After years of unrest, Egypt was formally granted

independence late in 1922. The ever-resistive Egyptian culture had survived its greatest test and emerged from the colonial period largely unchanged. Still, the vast majority of Egyptians remained Islammic (Moslem).

Wilbur (1969) reveals that the basic structure of the Moslem society of Egypt shows no influences of alien cultures and religions. In this respect Egypt is different from India, where the caste system of the Hindus led to the establishment of classes of Moslems. Moslem marriages are usually arranged. Islammic law allows a man up to four wives and many concubines. (Tritton 1951) Thus, a typical household is a joint system which combines several families having blood relationship to the patriarch. Moslems have a well-developed sense of responsibility to their families because the Koran lists failure to do one's duty to the family or tribe as a grave sin. Moslems also have a sense of brotherhood with all other Moslems which extends this feeling of responsibility. (Tritton 1951)

Management Structures

Egypt, rooted in the North African desert and watered by the mighty Nile, developed a strong agricultural economy in ancient times. In the modern colonial era, its raw cotton and other agricultural products were its contribution to Britain's strength and its means of paying for the manufactured goods sent from Britain. With independence, the need for embarking on an internal industrialization process was acute. The first industry to develop was textiles in the 1920s. Later the industrial base was broadened by the development of the furniture, shoe-making, and tobacco industries.

Several aspects of Islam directly affect business practices. Tritton notes that Islammic law forbids the collecting of interest or the selling of something not yet produced. Business is generally conducted with few written documents and verbal contracts are binding if four witnesses are present. These ideas, combined with the feeling of the universal brotherhood of Moslems, lead to a business environment that is not highly aggressive or profit-oriented. Modern Egyptian industry is strongly affected by governmental policies and in many ways acts as an arm of the government in pursuing national goals. (Wilbur 1969) In this way, businessmen are able to discharge their responsibility to the Islammic brotherhood.

## INDIA

Historical Perspective

India's history is a series of conquests, ending in the British Raj (rule). This period was the most influential because the British ruled with a strong hand. During the eighteenth century, when the West and Japan were transformed from agrarian to industrial societies, India remained agrarian. Reasons cited for this are the absence of individualism, lack of incentives to industrialize, emphasis of culture on spiritualism rather than material values, and a deliberate policy of the British. (McNeil 1967)

The origin of India's caste system is obscure, although it originated (around 1500 B.C) to separate the fair skinned Aryans from the darker people they conquered. There are four different castes: priests, warriors, traders, and workers. The effect of religion in India is in marked contrast to the effect of religion in Japan and the United States. About 80% of the Indian population is Hindu; the other 20% is Moslem, Christian, Sikh, Jain, Buddist, and Parsi. Each of these groups tends to be a separate community with its own customs, traditions, habits and marital exclusiveness. This religious and social separation extends into the economic sphere as well because it compartmentalizes society with the observance of divisions sometimes assuming more importance than management of business. (Prasad and Neganhi 1968)

India is a familial society similar to Japan, but this familism has tended to hinder the development of effective management. Most Indian families are large extended families, joined together in eating, worshipping, holding property and decision making. This strong family tie partially masks unemployment and has a profound effect on personal attitudes towards authority and individual initiative. The resulting expectations as to what government officials, private executives or other persons with power or influence should do for their families are entirely different than in the West. (Lamb 1964) Chowdhry (1966) believes that young Indian executives live in an atmosphere of conflict. They are torn between obligations to the family and community, norms of the profession and demands of technology.

Management Structures

Before independence in 1947, almost all businesses were privately owned and managed. With independence the nation embarked on the path of democratic socialism. Historically, Indian management has employed the patrimonial system. (Dhingra and Pathak 1973)

Indian management structures have their origins in the system developed by the British. 'Indian managing agencies' were family enterprises in which the son followed the father's footsteps (Basu 1958). Although managing agencies have been abolished, management of private enterprise is centralized and personal. Typically the family is headed by the eldest male and his delegation of authority is extremely limited. Recruitment is highly subjective with most positions going to

relations. In recent years more management authority has been entrusted to professionals and a more bureacratic style introduced. A pervasive presence of government exists at every level of decision making.

Since independence, there has been considerable development of Indian managerial talent in India. Tandon (1972) felt that the new managers would be a synthesis of Indian culture, their loyalties broad, and their values and standards new. It is noteworthy that despite India's long standing ties with Great Britain, most managers seek their education in the United States. The influence of American views of management is expected to exert considerable influence in the ranks of Indian executives for a long time to come.

## UNITED STATES

### Effect of Culture on U.S. Management Practices

The culture of the United States has often been described as pluralistic, meaning that many different cultures contributed to the national life (Long and Seo 1977). Different customs may be observed not only in different sections in the society but also among people of different national origins. These differences are cherished by a society which believes in the right of an individual to choose for himself. Indeed, children are taught to make individual decisions while college training for business executives emphasizes the techniques of decision making under varying circumstances.

Many historians credit the rise of modern capitalism and industrialization of the West to a change in religious attitude. In the Middle Ages, the Roman Catholic Church regarded trade as a necessary evil, and any profit in excess of a wage for the trader's labor was evidence of the sin of avarice. Calvinism, which followed the Reformation of 1517, developed the Protestant ethic, which sees work as a positive good in and of itself, holding that the ability to accumulate wealth is a sign of God's grace. The Protestant ethic legitimized the pursuit of profit and thus enabled the tremendous industrial expansion that took place in the United States after the Civil War. In 1517, Martin Luther challenged the church's separation of religious and secular life. Calvinism, which followed, developed the Protestant work ethic. Later, with the publication in 1776 of Adam Smith's treatise An inquiry into the wealth of nations, the theory of capitalistic ethic was born. Under Adam Smith's theory of laissez faire, the best possible allocation of resources for the benefit of society takes place when each individual pursues his own best interest. Smith's doctrine was reinforced by the concept of social Darwinism or the survival of the fittest. What was published as a scientific discovery soon extended into the broader reaches of society. (McNeil 1967)

The Protestant ethic and the bureaucratic system have become imperative values of American organizational life. Top management not only shares in, but is also controlled by, these values. Lange (1982) writes that "top management can afford to identify with the ethic because they have attained their individuality and their corporate success. But because of the pyramidal structure of bureaucracies, very few attain these goals. The great majority are not destined to succeed, but are expected to identify with these values."

## SUMMARY AND CONCLUSIONS

Some differences between countries are summarized below. This table shows the variations in family structure and views on materialism that result from adherence to the primary religion in a country.

| Religion (Country) | Family Structure | Views on Materialism | Management Structure |
|---|---|---|---|
| Judeo-Christian (U.S.) | Loose Family | Protestant Work Ethic | Individual Success Stressed |
| Buddhism (Japan) | National Family | Wealth Supports Family | Consensus Stressed |
| Hinduism (India) | Extended Family | Neutral | Patrimonial/ Bureaucratic |
| Islam (Egypt) | Joint Family | Sprirtualism Stressed | National Goals Stressed |

In conclusion, a nation's primary religion has a strong influence on its predominant management structure. Religion affects management and business practices primarily by influencing family structure and society's views on materialism. Management structures and business practices which are largely consistent with such religious and societal beliefs will tend to be the norm in the country.

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# TECHNOLOGY TRANSFER IN DEVELOPING COUNTRIES: THE CASE OF THE BURUNDI PEAT STOVE

Cynthia L. Tobias
University of Arizona
Tucson, Arizona

## ABSTRACT

Due to the severe deforestation and subsequent shortage of the traditional cooking fuels, firewood and charcoal, and to the absence of any other native energy resources, Burundi looked to its vast peat reserves as a potential alternative fuel. This project sought to evaluate the receptivity of urban women in Bujumbura, the capital, to a change in their primary cooking fuel from charcoal to peat. A household energy use survey was conducted to determine habits and preferences. A prototype very low cost peat cooking stove was then built in several households and subsequently modified to suite local practices. Overall acceptance was found to be generally good, and is partly attributable to the intense involvement of users in the design and testing process.

## BACKGROUND

Burundi is a small landlocked country in central Africa, formerly part of the Belgian Congo. About 95 percent of the population of about 4.5 million is engaged in subsistence agriculture. Population densities reach 350 inhabitants per square kilometer, even in rural areas. Coffee is the principal export and a large amount of foreign exchange is used to import petroleum products along a costly land route running through Kenya, Uganda, and Rwanda. These products are consumed primarily in urban areas and by the military.

Over 95 percent of the energy consumed in Burundi is in the form of woodfuels or agricultural residues, which are gathered rather than sold in the rural areas. Urban dwellers consume proportionally more wood than their rural counterparts, generally in the form of charcoal. Some estimates are that the capital city, Bujumbura, which accounts for about 4 percent of the population, consumes 25 percent of the fuelwood (World Bank, 1982).

Burundi has vast unexploited peat reserves which may provide an alternative fuel source, if they can be harvested at a reasonable cost without serious ecological damage (they retain vast amounts of water and some bogs are important for dry season agriculture) and if people will accept peat as a suitable fuel. Peat is the first stage in the process of decomposition of plant remains which over time leads to coal. It has a low ignition temperature and burns easily and completely under proper conditions. Proper burning procedures, providing both primary and secondary air sources, are required to avoid the production of volatiles (smoke) (Bord Na Mona). It has been estimated that Burundi has 100-200 million tons of peat, some of it currently used for dry season food production. However, the quality is not as good as that found in Ireland.

## INTRODUCTION

This paper summarizes the activities and conclusions of a project designed to test the receptivity of urban women in Bujumbura, Burundi to a change in their primary cooking fuel from charcoal to peat. It was part of a larger, multiyear project, funded by the U.S. Agency for International Development, and administered locally by Catholic Relief Services. The objective of the larger project was to assess the feasibility of utilizing Burundi's vast peat reserves as a commercial and household fuel. The project component described in this paper focused on the household market in the capital city, and was staffed by a sociologist (myself), assisted by an interpreter/interviewer and a stove designer. It was carried out during a four month period in Burundi.

The household energy component was divided into two phases. The first phase consisted of a household energy use survey carried out in four "quartiers" or neighborhoods, inhabited primarily or exclusively by Africans. The second phase consisted of the construction of peat stoves in selected households, an assessment of the need for design modifications and their implementation, and an evaluation of their effectiveness and acceptance.

## HOUSEHOLD ENERGY USE SURVEY

Based on 1980 census data, the four neighborhoods selected for the survey accounted for 51 percent of the total households of Bujumbura, and represented both

low and middle income African communities. One of them was a suburban community inhabited almost exclusively by low income native Burundians, many of whom were new arrivals to the city. Two more included both low and middle income households and were inhabited both by native Burundians and by Rwandese refugees. The fourth was a generally low income mixed neighborhood close to the city center.

Households were selected for inclusion by a quota sampling technique, based on housing maps and visual inspection. An attempt was made to get an even distribution of houses with straw roofs, the poorest and most traditional, metal roofs, indicative of a slightly higher income and integration into urban life, and those with electricity, a sign of wealth. These distinctions were used as an approximate measure of income level, since pilot work indicated that the typical respondent, a wife or a houseboy, had no idea what their household income level was. The total sample size was 121 cases, representing .8% of the total households in the four areas or .4% of the total households in the city. As in many developing countries, the sample size was affected by the resources available.

The questionnaire consisted of 27 essentially closed-ended questions, administered in French, Kirundi or Swahili as required, by the sociologist or a local female school teacher. The questions concerned demographic characteristics, cooking practices and preferences, food preferences, fuel purchasing habits and familiarity with community service centers.

Although one or two questions were problematic, the interview process was generally trouble-free. No household refused to participate. We carried around a sample brick of peat and it elicited great curiosity, occasionally attracting large crowds of people. Great efforts were made to interview the respondent alone, but success in this regard was achieved in only about half the 121 cases, since the concept was culturally very alien.

The survey showed that most households cooked with charcoal, which they purchased daily in small quantities from a vendor located close to their home. Very few had the disposable cash to buy an entire sack at once, which would have greatly reduced their overall cost. Sixty-five to 87% of the households, depending on the community, cooked outside most of the year but moved inside during the rainy season. The more traditional households did all of their cooking squatting on the ground. Only one of the more middle class neighborhoods showed a minority (29%) cooking in that position. Most respondents indicated some doubt that a "block of dirt," as they called the peat brick, could actually burn. Several negative rumors about peat were identified which could affect its acceptability as a household fuel. One rumor was that it would eat holes in metal cooking pots, or in the commonly used (90-100%) charcoal burners. Another fear, not totally unfounded since often the peat bricks were improperly dried, was that it would produce clouds of unpleasant smoke.

Some implications of the findings for the cookstove development component included:
...Because of the fears about cooking with peat and because its combustion characteristics were quite different from charcoal, detailed demonstrations should accompany its introduction to the community
...Peat should be available for purchase in small quantities in many locations. It would not work if the government peat board (ONATOUR) tried to sell it in quantity at only a few locations.
...Charcoal sellers should be closely involved in any distribution program to allay their fears that their source of income would be lost if people changed fuels. Otherwise they would become enemies of the conversion and perhaps make it impossible.

## COOKSTOVE DEVELOPMENT

Phase two involved the development of a suitable, low cost cookstove prototype for peat. There were no appropriate peat cookstove models available in either the developed or the developing world. Irish peat stoves were generally made of iron, and would have been prohibitively expensive in Burundi. We looked instead toward the low cost fuel efficient stoves developed for other fuels, primarily firewood, in other developing countries. The first model was based on the magan choola of India and was constructed of scrap metal. Although this model appeared to burn effectively, once it had been modified to suit the combustion properties of peat, it was found to be too expensive.

The next model selected was the clay Lorena stove (Evans, 1979) developed in Guatemala. Because some women had indicated a desire to cook standing up (like rich women with gas stoves) instead of squatting on the ground, and because certain combustion characteristics of peat appeared to contraindicate a cheap, metal stove similar to that used for charcoal, this seemed a good choice. It is made of clay bricks covered with mud plaster. It must be noted that there was no "expert advisor", such as a heat transfer engineer, available to assist us.

The stove was built and modified by trial and error, with some assistance from the Evans book and miscellaneous documents available at assistance agencies, none of which discussed peat as a fuel.

Five stoves were constructed at houses throughout Bujumbura. The stoves incorporated a firebox connected to a tunnel system, allowing the use of three cooking pots at different temperature levels. Cooks generally found it hard to adjust to the idea of cooking food slowly. Peat does not reach the temperatures produced by the quick-burning, flaming Bujumbura charcoal, and the staple food, beans, took a much longer time to reach a rolling boil. Unfortunately, because it was the rainy season, the peat bricks often had a high moisture content which produced an intense and fairly unpleasant smoke, particularly when first ignited. Design and handling modifications somewhat resolved this problem. The end product was a square stove measuring about 100 by 110 cm. It was built primarily of clay bricks, covered by a mud plaster, mixed with cement where possible to reduce rainy season damage. Rings to hold the pots steady were made of scrap metal as were damper doors. Chimneys were generally made of scrap metal which eventually burned through, or to save cost, of large bamboo stalks, although we feared a fire danger from the latter. We felt that a fired clay chimney could be a good alternative, but could not find a potter to make it.

Overall acceptance was generally good. The households selected to have a stove prototype became the envy of the neighborhood. The negative rumors were disproved. Peat did not eat holds in the commonly used aluminum cooking pots. Some users eventually decided that beans tasted better cooked on peat than on charcoal. Although the first stoves were free, we eventually began to charge a small materials fee. The experiment was judged to be essentially successful and the project was completed.

## CONCLUSION

Various lessons can be learned from this project. One is that African women are by no means unwilling to accept innovations, even in such a traditional area as the preparation of their family's meals. Even when they could not obtain peat, they often sat their old charcoal burners on top of the clay stove, so they wouldn't have to squat. Another lesson is that men must also be involved in the cookstove process. Cooking is done outside the house in Bujumbura, and in the rainy season a clay stove soon suffers if it has no roof. Building even a simple straw roof is a male task, thus, without the spouse's help, the stove would soon be lost.

We concluded that for this sort of prototype testing it was essential to choose households where there was a serious interest in having the stove, and in which the cooks had at least a basic understanding of the experiment's purpose. This by no means implies a need for formal education. Some people simply felt uncomfortable giving negative feedback to outsiders who had given them a gift stove, and thus did not prove to be good subjects. Charging a modest fee for the stove made the users more willing to complain!

Both Burundi and Rwanda have vast unexploited peat reserves. Both are very densely populated and almost totally deforested. It appears that, if the peat could be readily harvested and moved economically to market, urban people would use it, even though it burns quite differently from charcoal.

More generally, this project emphasizes yet again the need for the human factors expert to do "hands on" work in the field with the potential users, when attempting to develop or transfer technology in developing countries. Had we only interviewed government officials, the stove would have turned out quite differently. In fact, we faced great opposition from them and from expatriate project leaders when we abandoned the expensive metal stove to develop the Lorena model. They were all quite sure that women preferred to squat on the ground to cook! Additionally, by involving the users and in fact, the community, in the design process and treating them as intelligent contributors, we generated an enthusiasm for peat as a cooking fuel which would never have occurred had we used a top down design methodology.

## NOTES

Special thanks are due to Riaz Gondal, who acted as the stove designer and co-collaborator on the prototype project, and to all the people of Bujumbura who so generously answered the multitude of unusual questions. Additional thanks are due to those families who dared to try cooking on a "block of dirt."

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