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A Classification System for Characterization of Physical and Non-Physical Work Factors

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A comprehensive evaluation of work-related perfomance factors is a prerequisite to developing integrated and long-term solutions to workplace performance improvement. This paper describes a work-factor classification system that categorizes the entire domain of workplace factors impacting performance. A questionnaire-based instrument was developed to implement this classification system in industry. Fifty jobs were evaluated in 4 different service and manu-

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facturing companies using the proposed questionnaire-based instrument. The reliability coefficients obtained from the analyzed jobs were considered good (.589 to .862). In general, the physical work factors resulted in higher reliability coefficients (.847 to .862) than non-physical work factors (.589 to .768).

performance work-factor system classification

1. INTRODUCTION

In today's business environment, worker performance is affected by a large number of work factors that span across the job, process, and organization levels. The identification and evaluation of the entire domain of work factors are, thus, crucial to developing integrated and long-term solutions to employee performance problems. A classification system is, therefore, warranted to characterize and assess this complex system.

A review of the scientific literature reveals a lack of comprehensive classification and assessment systems to evaluate the totality of factors impacting workplace human performance. Work factors can be classified into physical and non-physical factors. Most instruments dealing with physical work factors have concentrated on assessing some aspects of physical task demands (e.g., Karhu, Kansi, & Kuorinka, 1977; Keyserling, Stetson, Silverstein, & Brouver, 1993; Kemmlert, 1995; McAtmney & Corlett, 1993). Other instruments evaluated many aspects of both physical task demands and physical environment conditions (e.g., Guo, Genaidy, Christensen, & Huntington, 1996; McCormick, Jeannert, & Mecham, 1969; Rohmert & Landau, 1983). None of these instruments, however, can be used to assess the entire domain of physical work factors (i.e., physical task demands and physical work environmental conditions).

Although the NASA-TLX (Hart & Staveland, 1988) and SWAT (Reid & Nygren, 1988) are examples of well-known instruments designed to measure mental workload, they lacked many of the details required for a comprehensive assessment of perceptual and cognitive work requirements (i.e., mental task demands). The PAQ (McCormick et al., 1969), on the other hand, devoted enough attention to the assessment of perceptual task demands.

Several instruments in the stress research literature have measured non-physical environment conditions. In a comprehensive review of the published literature, Hurrell, Nelson, and Simmons (1998) evaluated the following instruments: stress diagnostic survey (Ivancevich & Matteson, 1984), work environment scale (Moos, 1981), job content questionnaire (Karasek, 1985), occupational stress inventory (Osipow & Davis, 1988; Osipow & Spokane, 1980, 1983), occupational stress indicator (Cooper, Sloan, & Williams, 1988), generic job stress questionnaire (Hurrell & McLaney, 1988), job stress survey (Spielberger, 1994), job diagnostics survey (Hackman & Oldham, 1975), and job characteristics index (Sims, Szilagyi, & Keller, 1976).

On the basis of their evaluation, Hurrell and co-workers (1998) have pointed out that the aforementioned instruments vary in both the number and type of non-physical environment conditions. The job content questionnaire and job stress survey, for example, capture global work requirements with their constituent scales summing across items that assess demands. The job diagnostics survey and job characteristics index are examples of instruments designed to assess job characteristics thought to be important in motivating workers and creating job satisfaction. Most of these instruments did not incorporate any of the physical work factors. Instruments such as the job content questionnaire, considered some of the physical work factors on a limited basis.

In summary, there is an urgent need to develop a classification system for the characterization of the synergistic effects of work factors upon the worker. This paper deals with such an application by developing a classification system to categorize the entire domain of workplace factors impacting performance. This system, referred to in this paper as the Work-Factor Analysis (WFA), integrated many of the items cited in the published literature with new elements added to it. The research reported herein is an extension of our earlier work on work system compatibility (Genaidy, Karwowski, Shoaf, & Welling, 2000).

A questionnaire-based instrument was developed to implement this classification system in industry (Genaidy & Karwowski, 2000). Employees populated in 50 jobs were asked to evaluate their jobs using the questionnaire-based instrument. Each evaluation was performed twice separated by a 2-week period. This was necessary to ensure that the data collected from these employees are reliable.

2. WORK-FACTOR CLASSIFICATION SYSTEM

2.1. Overall Classification

In this research, a work factor is defined as a load acting upon the worker in the business environment to produce an output required by the organization.

A load may be classified according to its effect into either "energy expenditure" or "energy replenishment." An energy expenditure load results in energy depletion; an energy replenishment load works as a stimulus that increases human energy reserves.

The class of energy expenditure loads represents a multitude of work factors and may be grouped into nine major categories, namely, physical and mental task demands; physical, chemical, biological, and radiological environment conditions; and social, organizational, and technical environment conditions (Figure 1).

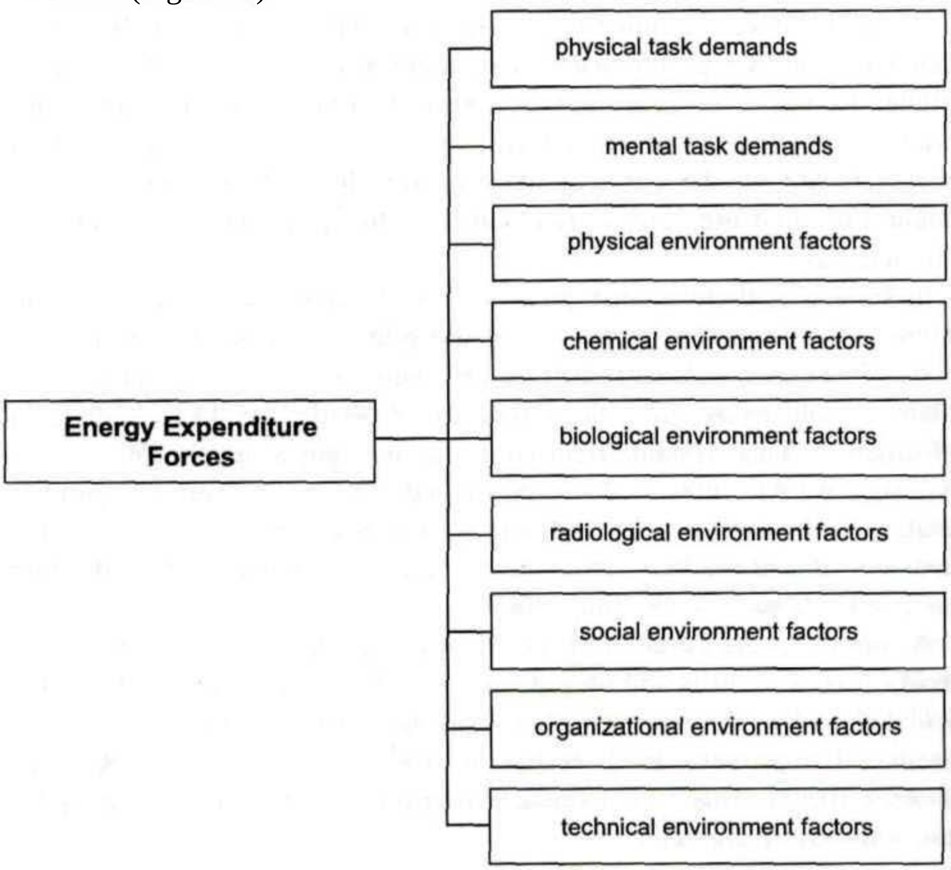

Figure 1. Overall classification of energy expenditure loads.

Physical task demands are considered physical requirements that necessitate muscular work. They deplete the worker's internal physical energy resources. Similarly, mental task demands are loads in the work environment that are imposed upon the perceptual and thinking processes of the worker. A consequence of these work requirements is the consumption of mental energy resources.

The physical environment factors are physical conditions in the workplace (e.g., noise, heat stress) that expend the three resources of human energy (i.e., physical, mental, and emotional). Also, the chemical (e.g., dust, fumes), biological (e.g., bacteria, viruses), and radiological (e.g., X-rays) factors are part of the physical environment conditions that drain all three resources of energy.

The social environment loads are demands imposed upon the worker due to work situations and conditions that require interaction with others in the organization (e.g., social conflict with the supervisor or co-workers). The organizational loads are demands in the work environment defined by how work is organized and structured (e.g., working night shift or long hours). The technical environment conditions deal with the adequacy of equipment, tools, skills, knowledge, and supervision required to alter materials or information in some specified or anticipated way to achieve a desired end result. The social, organizational, and technical environment conditions primarily influence the emotional energy exertion.

The energy replenishment loads are considered opportunities in the workplace that stimulate and motivate individuals to achieve work goals (Figure 2). These loads are dominated by the organizational and social environment conditions and are quite distinct and different from those classified as energy expenditure loads. They function by replenishing the emotional energy that, in turn, recharges the physical and mental energy resources (up to the allowable physiological limits).

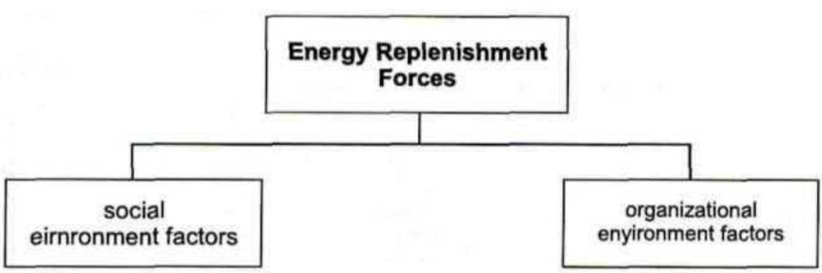

Figure 2. Overall classification of energy replenishment loads.

2.2. Classification of Energy Expenditure Loads

2.2.1. Physical task demands

The workload defined by physical task demands can be described in terms of the resulting muscular work. In **general,** muscular work consists of combinations of dynamic and static muscular exertions. Dynamic work is characterized by a rhythmic alternation of contraction and extension, tension and relaxation. Static work, on the other hand, consists of a prolonged state of muscular contraction, lasting longer than 4 s. Both dynamic and static components of muscular work must be analyzed to account for physical requirements.

Physical task demands are grouped in this research into two general classes of muscular work: object handling in upright position and other activities (Figure 3). Manual object handling activities in upright position are overall body activities that consist of moving objects with one or both hands while the body is an upright position. They are defined for handling activities performed during standing (i.e., lifting and lowering, pushing and pulling), walking (i.e., carrying, pushing, and pulling), and climbing (i.e., carrying) positions. A typical example is loading and unloading trucks. Handling activities performed in positions other than standing, walking, and climbing are grouped under the other activity category. An example of such activities is moving small parts while the body is in a seated position.

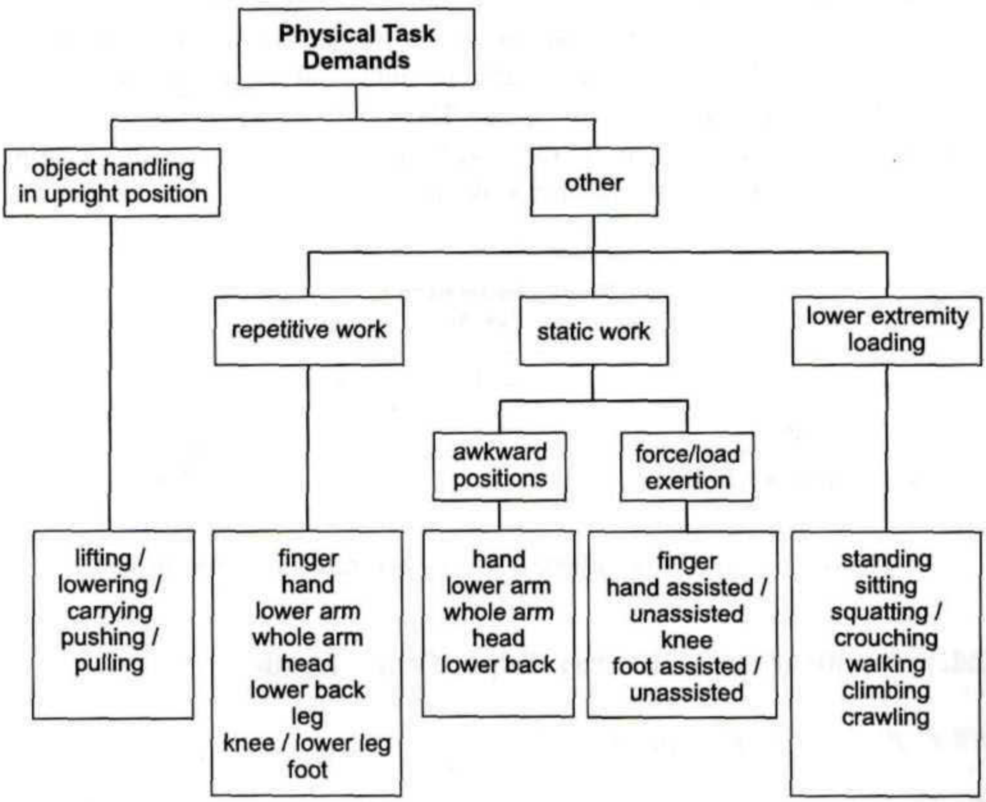

Figure 3. Classification of physical task demands (energy expenditure loads).

Object handling in the upright position is classified into lifting, lowering, carrying, pushing, and pulling. During lifting and lowering activities, a work object is moved vertically from a lower or a higher level to a higher or lower level. A carrying activity involves holding a load while the person is walking, climbing stairs and ladders, or crawling. A pushing or pulling activity involves pushing or pulling a work object either on flat surfaces and ramps (e.g., pushing hand carts) or on a work table (including conveyors). Other types of object handling work such as throwing bags and shoveling are classified under the other activity category (Figure 3).

The other activity category consists of all other types of muscular work, including those that involve moderate and heavier loads in positions other than the upright position. It is subdivided into repetitive work, static work, and lower extremity loading. Repetitive work includes activities performed by the following body parts: finger, hand, lower arm, whole arm, head, lower back, leg, knee, lower leg, and foot. Static work is classified in terms of awkward positions for different body parts such as hand, lower and whole arm, head, and lower back; and both continuous and discontinuous load and load exertion (for fingers, hands, and feet). Lower extremity loading includes static loading (e.g., standing, sitting) and dynamic loading (e.g., squatting, crouching, walking, climbing, and crawling).

2.2.2. *Mental task demands*

The mental task demand framework consists of two general classes of mental activities: skill-based and thinking-based (Figure 4). Each of the two major categories of mental work can be broadly categorized in three forms: steady state, transient, and simultaneous operations. Steady state operation describes a stable mode of workload with little variation in terms of the level of demands (i.e., difficulty) it imposes. In this case, work demands are relatively constant and continuous. Transient operation represents the period of transition and adjustment to a change in the level of work demands over a short period of time. Work demands may shift in an upward direction (acceleration) or a downward direction (deceleration). Simultaneous operations are activities performed at which time there may be a degree of interference between or among more than one activity.

Skill-based work represents those actions that are routine and executed automatically with little mental effort. Hence, skill-based work is perceptual in nature as information is processed almost automatically at the subconscious level. The worker's senses of hearing, vision, touching, smelling and taste, Object handling in the upright position is classified into lifting, lowering, carrying, pushing, and pulling. During lifting and lowering activities, a work object is moved vertically from a lower or a higher level to a higher or lower level. A carrying activity involves holding a load while the person is walking, climbing stairs and ladders, or crawling. A pushing or pulling activity involves pushing or pulling a work object either on flat surfaces and ramps (e.g., pushing hand carts) or on a work table (including conveyors). Other types of object handling work such as throwing bags and shoveling are classified under the other activity category (Figure 3).

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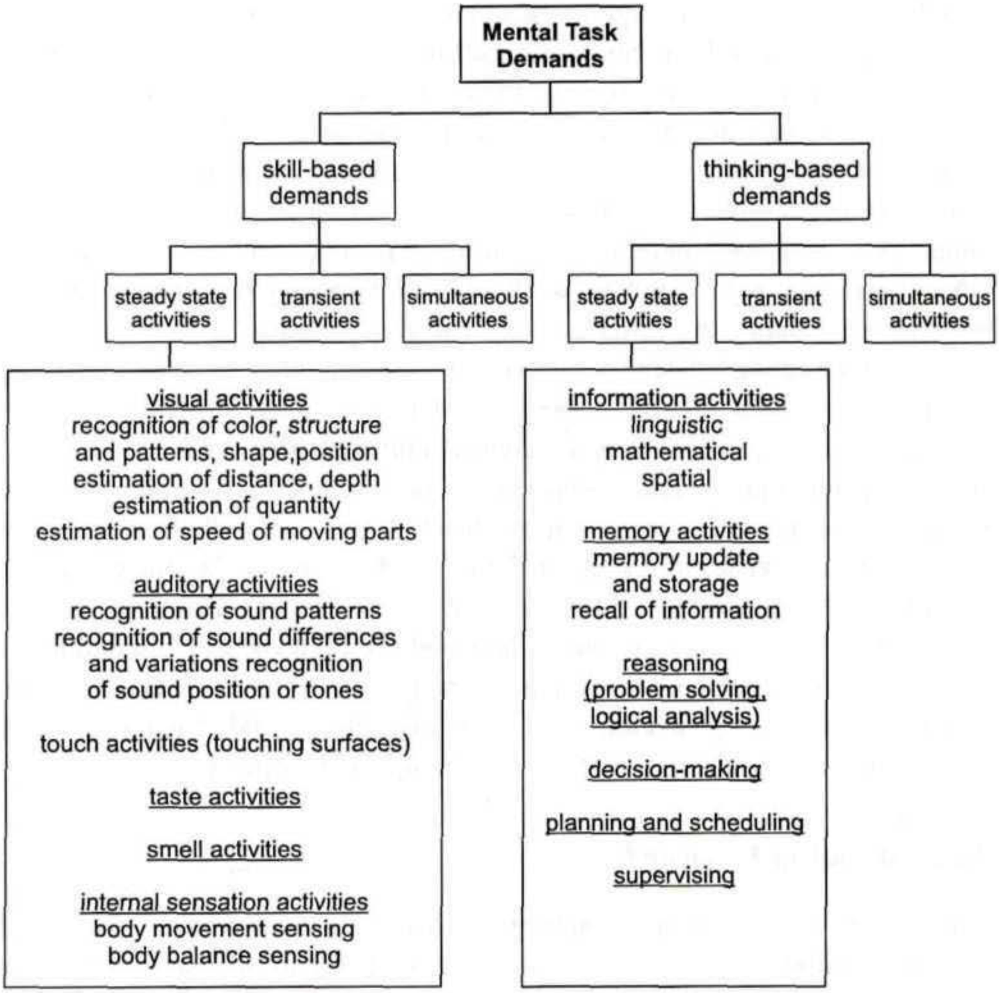

Figure 4. Classification of mental task demands (energy expenditure loads).

and balance function as the inputs to perceptual processing system. These inputs are the worker's mode of sensing. After the information is sensed, it is recognized and classified according to a previously stored pattern. The perceptual activity may end here or may progress to quantification, in which the information recognized is further refined.

Thinking tasks are mental activities that are performed in situations that are either familiar but not routine (i.e., acted upon by recalling past experiences) or unfamiliar. Thinking processing can be divided into four areas: information processing, memory work, reasoning, decision-making and planning and scheduling, and supervisory work.

Information processing can be further divided into three types of processing: word or symbolic (e.g., classification of events), mathematical (e.g., computing), and spatial manipulation (e.g., analyzing positions). Information processing activities described here require little or no decision-making. As such, it represents a lower level set of mental demands as compared to reasoning or planning, scheduling, and supervisory activities. Memory work, referring to memorizing, studying, and learning activities, plays a significant role in today's industrial environment that is continuously adapting to changes in technology and zealous market competition.

Reasoning represents a higher level of thinking processing, which requires the distilling of relational rules from the information presented. Activities such as problem solving and logical analysis constitute the reasoning facet of the thinking process. A decision-making activity is a complex process that should take into account the number and complexity of factors, variety of alternatives available, consequences and importance of decisions, background experience, education and training required, precedents available for guidance. Planning and scheduling as well as supervisory work is characterized by multi-attribute judgment requirements as several factors must be considered and weighed in order to select the optimal path.

2.2.3. Physical environment conditions

Physical environment factors are classified according to its source into physical, chemical, radiological or biological (Figure 5). Physical environment factors include noise (exposure to constant or intermittent sounds of a pitch or level); vibration (exposure to a shaking object or surface that causes strain on the whole body or extremities); illumination (amount of light at work surfaces, objects, general area); thermal stress (exposure to heat, cold, wind, humidity); changes in barometric pressure (effects of pressure due to altitude effects); kinetic hazards (due to falling or accelerating objects); mechanical hazards (e.g., hazards due to contact with sharp edges, contact with shearing devices, body part caught between two surfaces); fall hazards (e.g., trip and fall such as when a worker encounters an unseen foreign object, stump and fall such as when a worker's foot suddenly meets a sticky surface or a defect in the walking surface); immediately dangerous to life and health environments (e.g., electrical hazards, pressure hazards, fire arms): awkward or confining work space (i.e., conditions in which the body is cramped or uncomfortable); and hindrance of freedom of motion due to protective equipment, safety guard use, and awkward clothing.

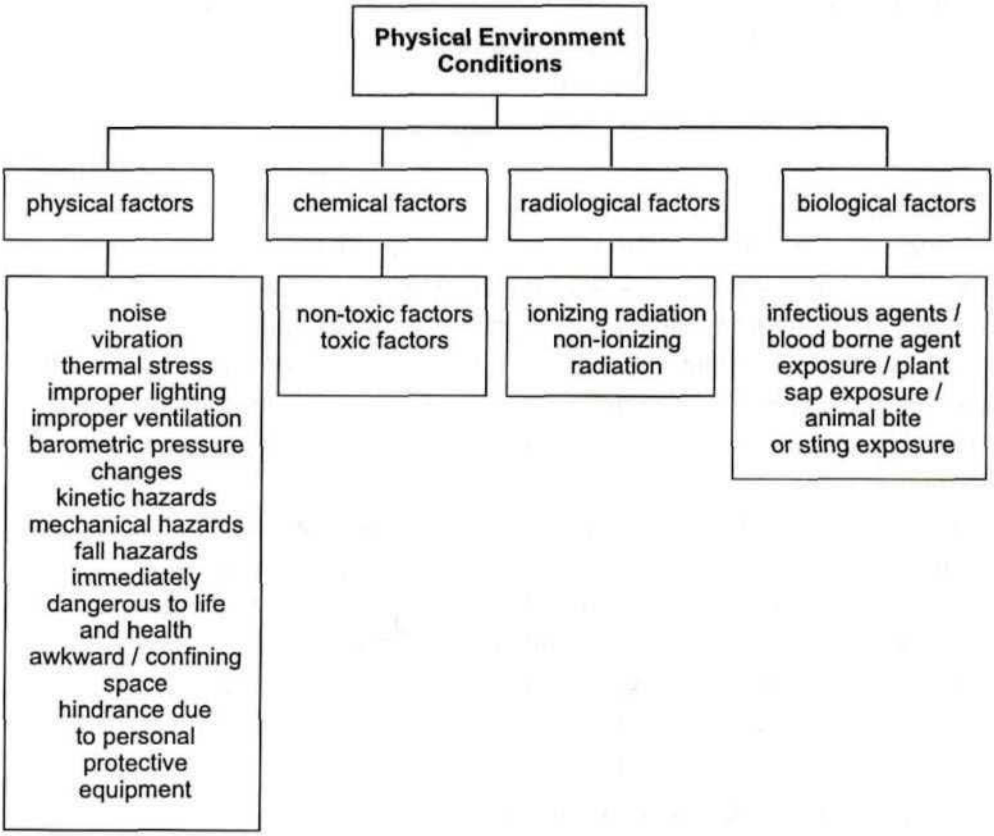

Figure 5. Classification of physical environment conditions (energy expenditure loads).

Chemical factors refer to the presence of metals, metal fumes, solvents, pesticides, plastics, gases, and dusts (i.e., particulate matter) in the physical work environment. They include non-toxic chemicals (e.g., dust and fumes) and toxic chemicals (e.g., solvents, carcinogens, carbon monoxide or other gases, metal fumes, heavy metals such as lead, arsenic).

Radiological factors include ionizing and non-ionizing radiation. Examples of ionizing radiation are X-rays, alpha, beta, gamma particles. Non-ionizing radiation includes such things as ultraviolet light, infrared, and lasers.

Biological factors are classified into infectious agents (e.g., bacteria, viruses, parasites), blood borne agents (e.g., medical worker exposed to needle-sticks), exposure to plant sap (e.g., poison ivy), exposure to insect bites (e.g., bees, wasps), and animal bites or stings (e.g., dog bites, snakes).

2.2.4. Social environment conditions

According to Figure 6, social factors are subdivided into social conflict (with individuals inside or outside the organization), interpersonal closedness (i.e., the way members of the organization do not relate to one another their ideas and feelings); freedom from prejudice (i.e., acceptance of the worker for work-related traits, skills, abilities, and potential without regard to race, creed, and national origin, or to life styles and physical appearance); mobility (i.e., existence or non-existence of upward mobility as reflected, e.g., by the percentage of employees at any level who qualify for higher levels); and fairness of complaints and disciplinary actions.

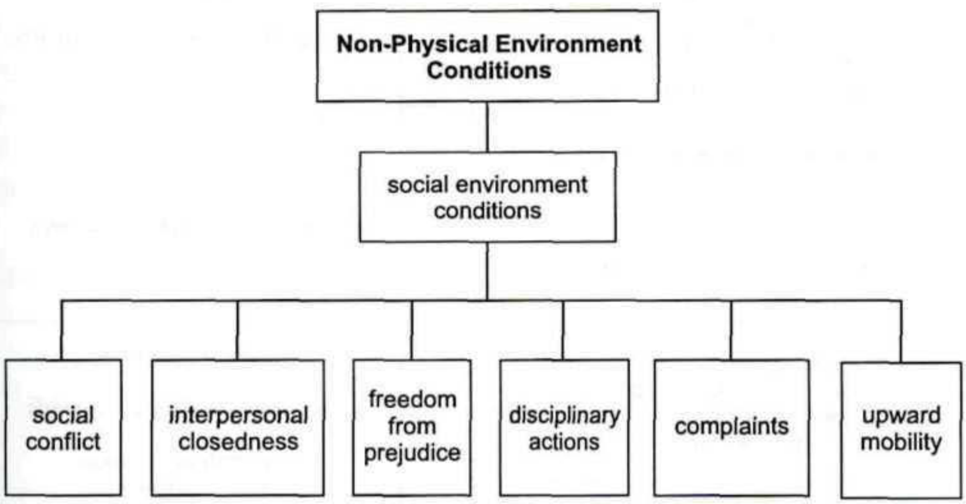

Figure 6. Classification of social environment conditions (energy expenditure loads).

2.2.5. Organizational environment conditions

Figure 7 presents a summary of the organizational environment classification that impacts energy expenditure. It consists of eight sub-categories: time organization (e.g., working night shifts), work responsibility (e.g., responsibility for lives and safety of others), compensation and income security (e.g., fairness and adequacy of base salary), logical sequence of work activities (for efficiency and effectiveness purposes), resource factors at the job, organization, and process levels (e.g., time availability for job performance), interface factors (i.e., collaboration between various functions), organizational design factors (e.g., organizational structure), process design factors (e.g., flow of information between jobs).

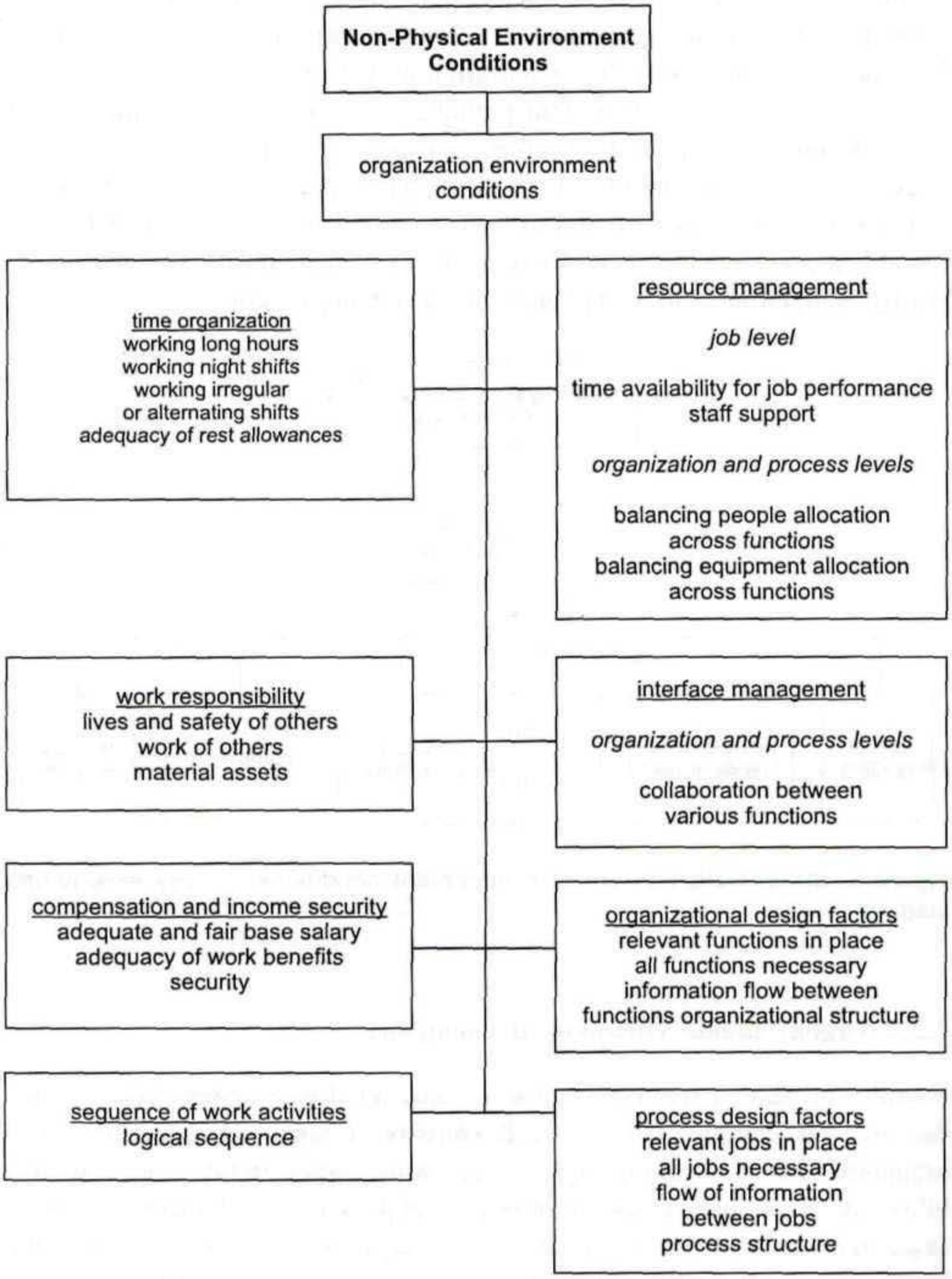

Figure 7. Classification of organizational environment conditions (energy expenditure loads).

2.2.6. Technical environment conditions

Factors in the technical environment determine whether the technology employed in the business enterprise is adequate with respect to the achievement of work goals (described in terms of work productivity, quality, and safety). Inadequate technical equipment, procedures, and expertise may severely compromise job performance because they contribute to added physical and mental task demands.

The technical environment conditions are classified into resource and skill and knowledge factors (Figure 8). Resource factors include the availability of right tools, equipment, machinery, and the quality of information received for job performance. Skill and knowledge factors assess the degree to which the necessary items are provided: (a) skills and knowledge (i.e., technical expertise required for job performance); (b) technical procedures (provision of technical procedures required to transform work inputs to outputs); and (c) technical supervision (presence of technically competent supervisor).

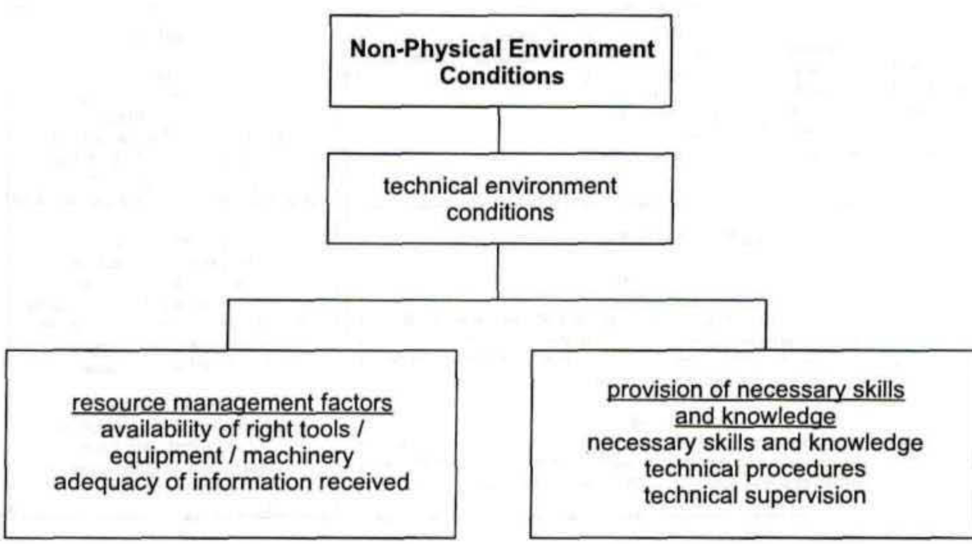

Figure 8. Classification of technical environment conditions (energy expenditure loads).

2.3. Classification of Energy Replenishment Loads

2.3.1. Organizational environment conditions

The organizational environment factors that impact energy replenishment are subdivided into autonomy, task organization, individual growth, reward, and knowledge of results (Figure 9). Those factors are distinct and different from those influencing energy expenditure.

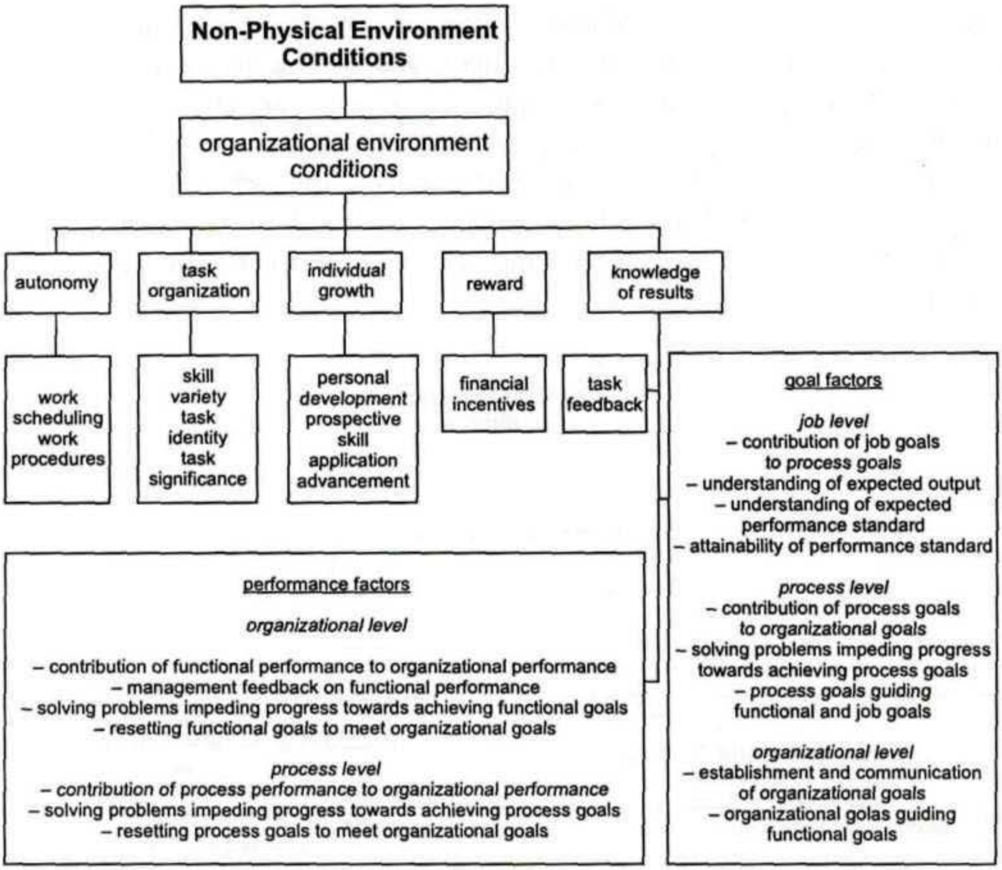

Figure 9. Classification of organizational environment conditions (energy replenishment loads).

Autonomy characterizes the degree to which the job provides substantial freedom, independence, and discretion to the worker in scheduling work and determining the procedures to be used in carrying it out (i.e., extent to which the job requires the worker to decide on his or her own to go about doing the work). Task organization is assessed in terms of skill variety (i.e., degree to which work presents the individual with a variety of skill requirements and talents); task identity (i.e., degree to which one is required to complete a "whole" and identifiable piece of work); and task significance (i.e., degree to which work has a substantial impact on the lives or work of other people whether in the immediate organization or in the external environment).

Individual growth deals with future opportunity for continued growth in an organization, and is manifested in terms of development (i.e., opportunities to expand capabilities rather than lead to obsolescence due to current activities such as work assignments and educational pursuits); prospective skill application (i.e., opportunities to use expanded or newly acquired knowledge and skills in future assignments); and advancement opportunities (i.e., opportunities to advance in organizational or career terms recognized by peers, family members, or associates). Organizational rewards are defined in terms of financial incentives designed to reward successful work over and above base pay, that is, bonus pay.

Knowledge of organizational results consists of task feedback (i.e., degree to which work is set up to provide information about performance, aside from that given by managers and co-workers); goal-oriented factors at the job (e.g., knowledge of how job goals contribute to process goals), process (e.g., knowledge of how process goals contribute to organizational goals), and organizational (e.g., communication of organizational goals) levels; and performance-oriented factors at the organizational (e.g., management feedback on functional performance) as well as the process (e.g., contribution of process performance to organizational performance) levels.

2.3.2. Social environment conditions

The social environment contributes to energy replenishment via social support (from members inside the organization), sense of community, interpersonal openness, social rewards, and knowledge of results (Figure 10). Social rewards include praise (i.e., opportunities to receive recognition for successful completion of work, aside from financial incentives); nurturing (i.e., opportunities to receive guidance for successful completion of work); and participation in decision-making (i.e., opportunities to get involved in important organizational decisions). Knowledge of results is centered around feedback information provided by managers and co-workers.

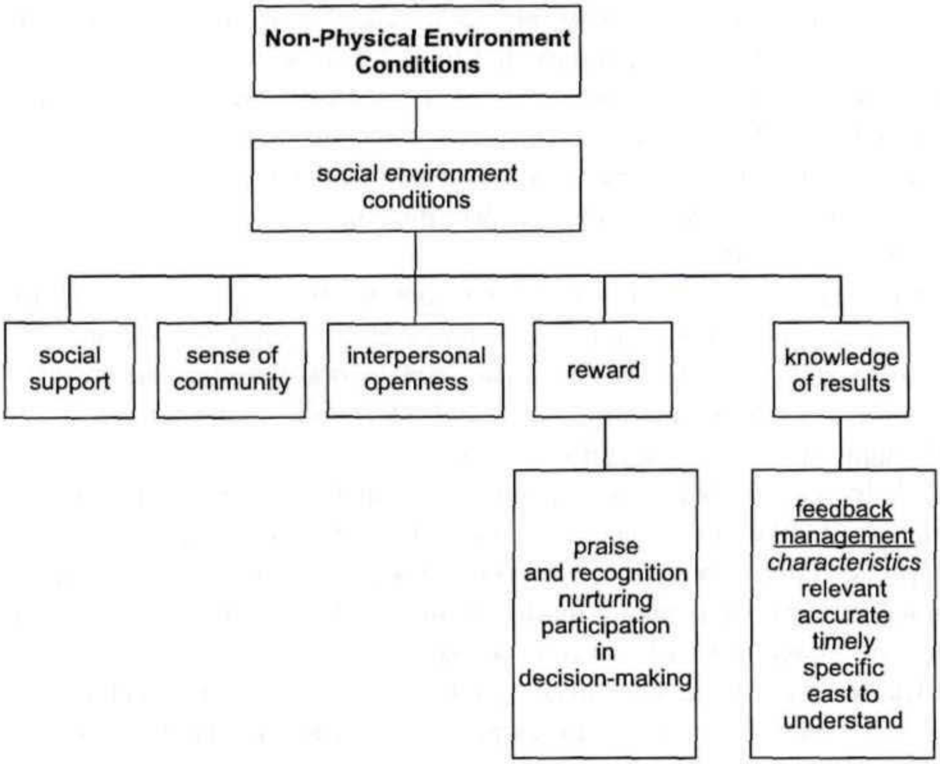

Figure 10. Classification of social environment conditions (energy replenishment loads).

3. APPLICATION OF WORK-FACTOR ANALYSIS IN INDUSTRY

3.1. Development of Questionnaire-Based Instrument

On the basis of the WFA classification system described in the previous section, a questionnaire-based instalment was developed to evaluate work requirements and conditions in industry (Genaidy & Karwowski, 2000). The instrument consists of 180 work factors that provide a broad coverage of work requirements and conditions.

Each factor is assessed using an 8-point rating scale. A typical scale is 0—*not applicable,* 1—*very small,* 2—*small,* 3—*somewhat small,* 4—*moderate,* 5—*somewhat high,* 6—*high,* 7—*very high.*

If a work factor is classified as an energy expenditure load, a higher value of this factor implies a more negative effect upon the worker than a lower value. On the other hand, if a work factor is classified as an energy replenishment load, a higher value of such a factor translates into a more positive effect upon the worker.

All work factors represent the elements of 11 global rating scales, 9 energy expenditure rating scales (i.e., physical task demands; mental task demands; physical, chemical, biological, radiological environment conditions; social, organizational, technical environment conditions); and 2 energy replenishment rating scales (i.e., organizational and social environment conditions). Each global scale can also be structured in a hierarchical fashion to provide additional details as needed.

3.2. Application Methods and Procedures

The questionnaire-based instrument was applied in four different service and manufacturing companies. Fifty jobs were evaluated in these companies. Each employee was asked to evaluate his or her work requirements and conditions twice separated by a I-week period. This was performed to determine the reliability of data collected.

Prior to the start of the study, each employee was given a briefing about the goal of this research, as well the highlights and background of the questionnaire. The reliability analysis was conducted using the test-retest methods of the Statistical Analysis Software [SAS] package (SAS, 1985). Descriptive statistics were also generated using the SAS package.

3.3. Application Results

The test-retest results of work factor assessment are presented in Table 1. The reliability coefficients obtained from the 50 analyzed jobs were considered good (.589 to .862). Physical work factors resulted in higher reliability coefficients (.847 to .862) than non-physical work factors (.589 to .768).

TABLE 1. Reliability Results for Questionnaire-Based Instrument

Type of Load		Reliability Coefficient
Energy expenditure loads	Overall	.722
	Physical task demands	.862
	Mental task demands	.768
	Physical environment conditions (physical, chemical, biological, radiological)	.847
	Social environment conditions	.693
	Organizational environment conditions	.681
	Technical environment conditions	.755
Energy replenishment loads	Overall	.776
	Social environment conditions	.589
	Organizational environment conditions	.701

The overall energy expenditure and replenishment load scales were within the *moderate* and *somewhat high* range values, respectively (Table 2). This indicates that there is a good degree of compatibility between the work factors that consume energy resources and those that motivate and stimulate the workers.

TABLE 2. Evaluation Results of Work Requirements and Conditions in Industry

Type of Load		Session	*M*	*SD*
Energy expenditure loads	Overall	1	4.06	0.71
		2	4.10	0.80
	Physical task demands	1	3.82	1.32
		2	3.75	1.43
	Mental task demands	1	4.25	0.88
		2	4.23	1.09
	Physical environment conditions (physical, chemical, biological, radiological)	1	3.31	1.42
		2	3.22	1.47
	Social environment conditions	1	4.88	0.90
		2	4.67	1.03
	Organizational environment conditions	1	4.43	0.64
		2	4.39	0.61
	Technical environment conditions	1	5.23	1.09
		2	5.13	1.00
Energy replenishment loads	Overall	1	4.71	0.78
		2	4.58	0.78
	Social environment conditions	1	4.56	1.11
		2	4.36	1.04
	Organizational environment conditions	1	4.78	0.75
		2	4.68	0.75

Notes. Scale: 1—*very low*, 2—*low*, 3—*somewhat low*, 4—*moderate*, 5—*somewhat high*, 6—*high*, 7—*very high*.

With respect to the elements of energy expenditure loads, physical and mental task loads as well as organizational environment load scored *moderate* values. Social and technical environment loads were considered *somewhat high*. These results demonstrate that both conditions require marginal improvement to bring them within the *moderate* range. The physical environment conditions were considered good (reported as *somewhat low)*.

With respect to energy replenishment loads, social and organizational environment loads scored *somewhat high* values. This set of results shows that the four different companies are instituting good work practices and procedures that stimulate and motivate their workers. Thus, no improvement is required in this regard.

4. CONCLUDING REMARKS

The work system (i.e., company or organization) is considered a complex system because it consists of a large number of work factors. An evaluation of factors is an important task for optimizing human performance in the workplace. In this paper, a methodology was described to manage the complexity of the entire domain of work factors by developing the architecture for a work-factor classification system. In this system, work factors are defined as loads acting upon the worker in the business environment. According to its effect, a load is classified into either energy expenditure or energy replenishment load. An energy expenditure load results in energy depletion; an energy replenishment load works as a stimulus that increases human energy reserves. In this paper, we laid out the details of the energy expenditure and replenishment load classification.

A questionnaire-based instrument was developed to implement the WFA in industrial settings. Fifty jobs were analyzed in four service and manufacturing companies. Each employee was asked to evaluate the work requirements and conditions twice to determine the reliability of data collected. Overall, the reliability of questionnaire-based instrument was good.

The research reported in this paper should be carried further to establish a metric system for the physical and mental task loads; physical, chemical, biological, and radiological environment load; and social, organizational, and technical environment load. This metric system should then be tested with respect to outcome measures such as health outcomes, work productivity, and safety, as well as output quality. Furthermore, the concept of work-factor compatibility introduced by Genaidy et al. (2000) as the degree of balance between energy expenditure and replenishment loads in a company should be tested to determine its viability as a methodology to optimize workplace human performance.

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