

This article was downloaded by: [185.55.64.226]

On: 08 February 2015, At: 11:08

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



International Journal of Occupational Safety and Ergonomics

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/tose20>

Assessing the Compatibility of Work System Factors Through an Integrative Model: A Case Study

Scott Wallace^a, Christin Shoaf^a, Ashraf M. Genaidy^a & Waldemar Karwowski^b

^a Department of Mechanical, Industrial and Nuclear Engineering, University of Cincinnati, OH, USA

^b Department of Industrial Engineering, University of Louisville, KY, USA
Published online: 08 Jan 2015.

To cite this article: Scott Wallace, Christin Shoaf, Ashraf M. Genaidy & Waldemar Karwowski (2003) Assessing the Compatibility of Work System Factors Through an Integrative Model: A Case Study, *International Journal of Occupational Safety and Ergonomics*, 9:1, 27-35

To link to this article: <http://dx.doi.org/10.1080/10803548.2003.11076552>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Assessing the Compatibility of Work System Factors Through an Integrative Model: A Case Study

Scott Wallace
Christin Shoaf
Ashraf M. Genaidy

Department of Mechanical, Industrial and Nuclear Engineering,
University of Cincinnati, OH, USA

Waldemar Karwowski

Department of Industrial Engineering,
University of Louisville, KY, USA

Work Factor Compatibility (WFC) theory proposes that human performance is dependent on the interaction of various components (e.g., physical and mental task demands, physical environment, social environment) of the work system and integrates multiple human performance perspectives into a single mathematical model. Work Factor Analysis (WFA) is a comprehensive survey administered to employees to determine the WFC index. WFA also provides recommendations for targeting specific work system areas for improvement. Preliminary testing of the tool was conducted at a manufacturing operation of a Fortune 10 company. Results are discussed and recommendations for further study are made.

human performance work improvement workplace assessment

1. INTRODUCTION

1.1. Background

Business managers are continually searching for methods to improve human performance and therefore increase productivity. Prior efforts to optimize

Correspondence and requests for offprints should be sent to Ashraf M. Genaidy, Department of Mechanical, Industrial and Nuclear Engineering, University of Cincinnati, Cincinnati, OH 45221-0072, USA. E-mail: <ash.genaidy@uc.edu>.

human performance have considered subsets of work factors on selected outcome measures in the work system (Genaidy, Karwowski, & Shoaf, 2002). For example, ergonomics and human factors efforts have traditionally focused on the study of task content (i.e., physical and mental task demands) as it affects work injury and illness rates. The Job Characteristics Theory (Hackman & Oldham, 1975, 1976) focused on job motivational factors (i.e., autonomy, skill variety, task identity, task significance, and task feedback) as they affect work satisfaction. However, with the acknowledgment of the significant interactive nature of task, environmental, social, individual, and organizational work factors (Ackoff, 1994; International Labour Office, 1986; Kuorinka & Forcier, 1995; Shannon, Robson, & Sale, 2001), the focus of work system analysis must be expanded. Recent efforts have begun to analyze work from the perspective of job demands and rewards (Karasek & Theorell, 1990; Siegrist, 1996). To continue these efforts, a comprehensive methodology for assessment of the work system must be developed.

In the workplace, human performance is influenced by numerous factors from various components in the work system. The work system can be classified into the following components: physical and mental task demands, physical environment, non-physical environment (Shoaf, Genaidy, & Shell, 1998; Shoaf et al., 2000). These components must be addressed through an inclusive study as they are both additive and interactive in their effect. Shoaf et al. (1998) described an integrative model of the work system. Work Factor Analysis (WFA) and Work Factor Compatibility (WFC) theory advance this previous work by providing a method to collect data and evaluate the work system.

WFC theory considers all integrative model components to determine the degree to which the current work system environment is optimal for human performance (Genaidy et al., 2002). WFC proposes that productivity is a function of the energy expended (i.e., energy expenditure) by the employee and the energy from the work system the employee requires in return (i.e., energy replenishment). The relationships of the various loads affecting energy expenditure and energy replenishment are depicted in Figure 1. The WFC index predicts that the best opportunities for optimal productivity exist when both energy expenditure and energy replenishment levels are high.

WFA is the tool developed to measure the WFC of a work system (Genaidy et al., 2002). It is an intensive set of survey questions, which measure the employees' level of energy expenditure and energy replenishment. The content of the questions are a composite of surveys developed to assess specific subsets of work factors by prior research efforts.

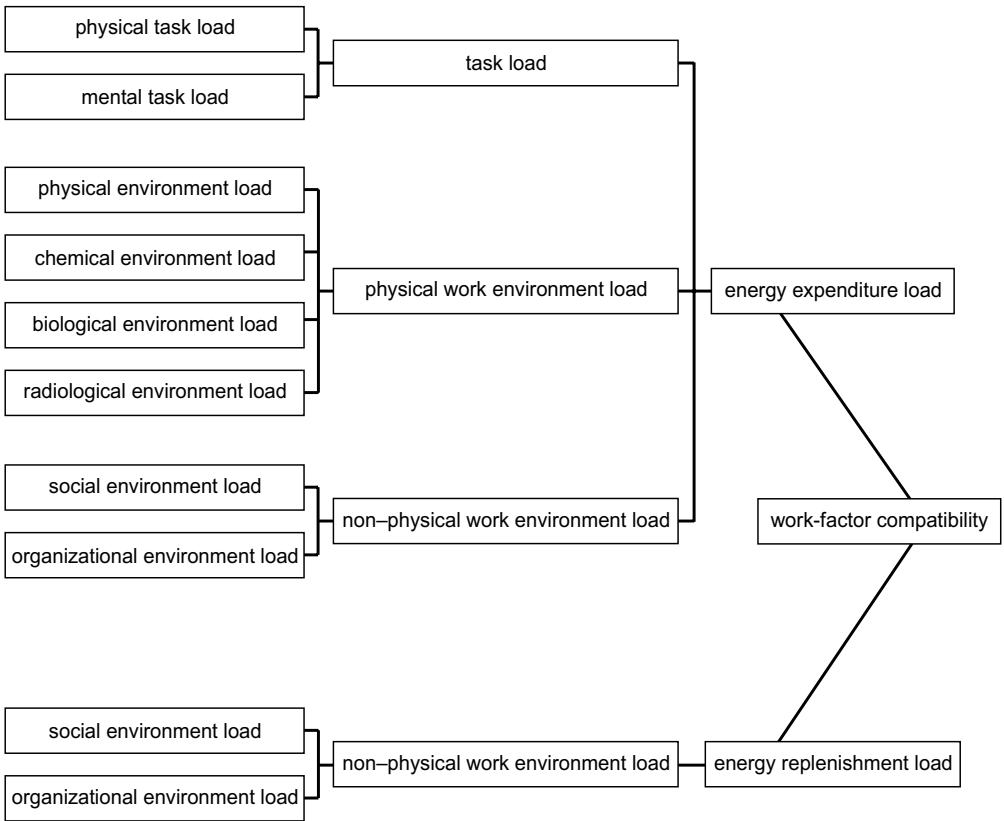


Figure 1. Work factor load hierarchy.

1.2. Study Objective

The objective of this study is twofold: (a) to propose a methodology to assess Work System Compatibility (WSC), and (b) to apply WFA to a manufacturing work operation in a Fortune 10 company to determine WFC and make a preliminary assessment of its practicality and benefit as a measurement tool.

2. DEVELOPMENT OF WFC METHOD

2.1. WFC Definitions

Work factors, elements in the work system resulting from requirements, conditions, practices and procedures in the environment, act on the worker as “loads.” In the work system, a load may be classified according to its effect

into either “energy expenditure” or “energy replenishment” load. An energy expenditure load (e.g., the manual handling of objects, solving complex mathematical problems, or an excessively noisy environment) leads to energy consumption and therefore has an adverse effect. On the other hand, an energy replenishment load (e.g., good financial incentives, social support) acts as a stimulus that helps activate human energy reserves and therefore has a positive effect. The relationship between the energy expenditure load (EEL) and energy replenishment load (ERL) defines the degree of Work Factor Compatibility (WFC).

2.2. WFC Hypothesis

It is our hypothesis that the higher the work system compatibility, the better the outcome measures of human performance (fewer work accidents, injuries and illnesses, higher work productivity and output quality, and higher work satisfaction).

2.3. WFC Calculation

This section introduces the methodology used to calculate the WSC (Work System Compatibility) Index. An overview of the process can be summarized in three steps. First, EEL is calculated from the data describing the work factors that decrease the worker’s available energy for work. Secondly, ERL is calculated from the data describing the work factors that increase the worker’s available energy for work. Finally, the WSC Index is computed as a function of the relationship between EEL and ERL.

2.3.1. Calculation of EEL

EEL describes work content (i.e., physical and mental task demands) and work context (i.e., physical and a subset of non-physical work environment conditions) as these work factors adversely impact the worker’s energy load. The physical task demands are comprised of work factors that directly result in muscular effort exertion (e.g., repetitive arm work). The mental task demands encompass the work factors that directly result in mental effort exertion (e.g., planning and scheduling work). Similar to physical task demands, the mental task demands are evaluated in terms of both overload and cumulative exposure.

The physical work environment conditions are defined by physical (e.g., noise), chemical (e.g., toxic chemicals), biological (e.g., bacteria), and radiological (e.g., X rays) conditions in the work environment. These conditions affect both physical and mental effort consumption and can impact emotional effort consumption. The non-physical environment is defined by the social, organizational, and technical factors in the work system. Non-physical environment conditions directly impact emotional effort that in turn influences both mental and physical effort. It should be noted that the non-physical environment factors in the energy expenditure domain used to calculate EEL are distinct from those factors in the energy replenishment domain used in the calculation of ERL.

Data for the work factors is gathered from a questionnaire assessment of work systems called the Work Factor Analysis Instrument (Genaidy et al., 2000). Each factor is assessed on the following linguistic scale: *very low*—1, *low*—2, *somewhat low*—3, *moderate*—4, *somewhat high*—5, *high*—6, *very high*—7. After each area has been assessed, mathematical equations are used to calculate EEL.

2.3.2. Calculation of ERL

ERL describes the specific non-physical environment conditions, organizational and social factors, which serve to increase the worker's available energy. Thus, ERL has a positive effect on the worker. The social factors exist through the interaction with others in the organization and may include social support provided by supervisors, peers or subordinates, sense of community, interpersonal openness, and work in groups. The organizational factors are governed, among other things, by time organization, sequence of job activities, work responsibility, resource and interface management, and compensation and income security. After each area has been assessed, mathematical equations are used to calculate ERL.

2.3.3. Calculation of the WSC Index

The WSC Index, the degree of equilibrium between the energy expenditure and energy replenishment loads, can now be calculated from EEL and ERL. A panel of experts was convened to establish a set of guidelines from which the WSC Index (Table 1) is derived. Fundamentally, the WSC Index is determined by the level of balance between EEL and ERL. Therefore, when both EEL and ERL are at the same level, the "fit" is optimal as the forces are in equilibrium. Additionally, the following rules govern the WSC Index table:

1. The farther conditions deviate from the “Region of Optimality” (i.e., moving up or down in a column from the left to right diagonal in the table), the more the WSC Index, in most cases, will deteriorate. The only exception is in the far right column when ERL is greater than EEL and an improved WSC results.
2. EEL is weighted more than ERL in the determination of the WSC Index as energy expenditure has a greater impact on the energy replenishment. For example, when ERL is high (e.g., high social support and rewards) and EEL is extremely high, the WSC Index is low. If the work demands are lessened and EEL becomes very high and ERL remains high, the WSC Index improves to moderate.
3. Moderate levels of EEL and ERL result in a more favorable WSC Index than extreme levels. For example, moderate levels of both EEL and ERL result in a high WSC Index. Very high levels of both EEL and ERL result in a moderate WSC Index.

TABLE 1. Work System Compatibility Index

EEL	ERL					Sustainability
	Very Low	Low	Moderate	High	Very High	
Very Low	L	L	L	L	L	<div style="display: flex; align-items: center; justify-content: center;"> ↑ ↓ </div>
Low	L	M	M	M	M	
Moderate	L	M	H	H	H	
High	VL	L	M	VH	H	
Very High	VL	VL	M	M	M	

Notes. ERL— energy replenishment load, EEL— energy expenditure load. Work System Compatibility (WSC) scores are described according to 5 levels: VH (*very high*)—optimum conditions, maintain current conditions if we can, we can rarely experience this condition; H (*high*)—low priority change, continuous fine tuning, minor change; M (*moderate*)—secondary change in the short and intermediate terms, definite change in the long term; L (*low*)—high priority change, definite change in the short term; VL (*very low*)—urgent and immediate change, very high priority change.

If the work system compatibility is low, the specific work area or areas that contribute to the low calculation can be examined. The work factor load can be compared with the resources to determine where imbalances exist in the work system, identifying potential areas for redesign. For example, if the mental task compatibility is low, the task demands are not balanced with the individual’s mental task resources.

Downloaded by [185.55.64.226] at 11:08 08 February 2015

3. TESTING WFC METHOD WITH WFA

3.1. Background

The WFC method was tested with WFA at a Fortune 10 company with headquarters in the suburbs of a Midwest city in the USA. A significant portion of this company's income is generated from supplying spare parts. The majority of the spare parts are manufactured by various global suppliers and purchased by this Fortune 10 company for resale to its customers. Generally, the spare parts arrive at the Packaging Operation facility (PO) in bulk. The PO then unpacks and repackages the parts, typically one per container to prevent damage, and distributes them to the customers.

3.2. WFA Questionnaire

WFA (Genaidy et al., 2000) is a tool designed to determine WFC through a comprehensive survey given to employees to assess EEL and ERL. The WFA survey was administered to the PO employees. Each question characterizes an aspect of work determined significant by prior human performance theories. WFA differs, however, from the manner in which checklists are traditionally used in that instead of simply indicating the presence or absence of a work factor, a linguistic variable is employed to indicate the variable's level. This approach is recommended when a detailed characterization of work elements is required (Shoaf et al., 1998).

3.3. WFA Results

Five salaried employees in the PO completed the WFA survey on two occasions separated by 4 weeks. The overall correlation value between the two trials was 0.73 ($p < .0001$). For 4 of the participants the correlation ranged from .82 to .85. The remaining employee's correlation was under .48. The computed load values were used to calculate WFC. EEL and ERL were both computed as high values. The WFC for the PO was calculated to be very high. Therefore, the PO is predicted to be functioning at optimum conditions.

In terms of workplace metrics, the PO is very highly productive if it is packaging over US \$1.2 per order. Examination of internal PO data confirmed that this goal had been reached three times in the 5 months. This indicates that there is probable correlation between WFC and actual productivity.

3.4. Discussion

The PO's WFC score was closely correlated to its operational performance during the time period assessed. These results were not unexpected as significant resources are spent to ensure the area's success. The values resulting from WFA indicate that the employees rated productivity in the moderate range whereas the WFC score was very high. As the employees rated safety and quality as high to very high, these metrics drove the composite WFC parameter to very high.

EEL scored high as a result of the high level of the non-physical environment load (comprised of the Organizational and Social Environment loads), which was high as many employees reported anxiety concerning their job. The Physical Work Environment Load had no impact on the calculation of EEL as the PO working environment is generally free from physical, chemical, biological, or radiological hazards. ERL was also scored high primarily due to the high Organizational Environment Load, driven by the employees' reports that they are very satisfied with their company and their work organization.

Preliminary testing at the PO has determined that WFA is an acceptable tool for establishing WFC; however the questionnaire has two weaknesses that deter its effectiveness. First, it is too long to be used in the workplace. Secondly, some questions are awkwardly worded. Accordingly, the WFA instrument will be revised before future use. In summary, the PO is functioning well with moderate to high productivity and high to very high quality and safety. There is a good balance between EEL and ERL and therefore, very high WFC. There are no suggestions for work system improvements at this time as functioning is optimal.

4. CONCLUDING REMARKS

This paper presented a new methodology for improving human performance in the workplace. The WFA survey was developed to collect the data necessary to calculate the WFC function, which provides recommendations for work system redesign efforts. The WFA survey was administered in a PO of a Fortune 10 company, and the WFC was assessed. The very high WFC level was indicative of the PO's actual productivity, safety, and quality metrics during this period. The WFA survey should be improved based on the feedback gained from this application. Then, the WFC methodology can be tested on a larger sample size.

REFERENCES

- Ackoff, R. (1994). *The democratic corporation*. New York, NY, USA: Oxford University Press.
- Genaidy, A.M., Karwowski, W., & Shoaf, C. (2002). The fundamentals of work system compatibility theory: An integrated approach to optimize workplace performance. *Theoretical Issues in Ergonomics Science*, 3(4), 346–368.
- Genaidy, A.M., Karwowski, W., Succop, P., Kwon, Y.-G., Alhemoud, A., & Goyal, D. (2000). A classification system for characterization of physical and non-physical work factors. *International Journal of Occupational Safety and Ergonomics*, 6(4), 535–555.
- Hackman, J., & Oldham, G.R. (1975). Development of the job diagnostic survey. *Journal of Applied Psychology*, 60, 159–170.
- Hackman, J., & Oldham, G.R. (1976). Motivation through the design of work: A test of a theory. *Organizational Behavior and Human Performance*, 16, 250–279.
- International Labour Office. (1986). *Psycho-social factors at work: Recognition and control* (Occupational and Health Series, No. 56). Geneva, Switzerland: Author.
- Karasek, R., & Theorell, T. (1990). *Healthy work: Stress, productivity, and the reconstruction of working life*. New York, NY, USA: HarperCollins.
- Kuorinka, I., & Forcier, L. (Eds.). (1995). *Work related musculoskeletal disorders (WMSDs): A reference book for prevention*. London, UK: Taylor & Francis.
- Shannon, H.S., Robson, L.S., & Sale, J.E.M. (2001). Creating safer and healthier workplaces: Role of organizational factors and job characteristics. *American Journal of Industrial Medicine*, 40, 319–334.
- Shoaf, C., Genaidy, A.M., Haartz, J., Karwowski, W., Waters, T., Hancock, P.A., et al. (2000). A cybernetic model for assessment of work related musculoskeletal hazards and risks. *Theoretical Issues in Ergonomics Science*, 1(1), 34–61.
- Shoaf, C., Genaidy, A.M., & Shell, R.L. (1998). A perspective on work system analysis: Classification and evaluation of methods. *Ergonomics*, 41(6), 881–898.
- Siegrist, J. (1996). Adverse health effects of high effort/low-reward conditions. *Journal of Occupational Health Psychology*, 1, 27–41.