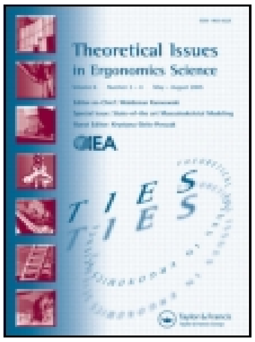

Theoretical Issues in Ergonomics Science

ISSN: 1463-922X (Print) 1464-536X (Online) Journal homepage: https://www.tandfonline.com/loi/ttie20

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To cite this article: Michelle M. Robertson & Theodore K. Courtney (2004) A systems analysis approach to solving office work system health and performance problems, Theoretical Issues in Ergonomics Science, 5:3, 181-197, DOI: 10.1080/1463922021000032320

To link to this article: https://doi.org/10.1080/1463922021000032320

THEOR. ISSUES IN ERGON. SCI.
MAY–JUNE 2004, VOL. 5, NO. 3, 181–197

A systems analysis approach to solving office work system health and performance problems

MICHELLE M. ROBERTSON* and THEODORE K. COURTNEY

Liberty Mutual Research Institute for Safety, 71 Frankland Road, Hopkinton, MA 01748, USA

Keywords: Office work; systems analysis; macroergonomics.

This paper describes a systems analysis approach to human performance in office work systems. The approach, integrating both micro- and macroergonomic aspects, provides a process for more comprehensive, systematic solutions. This systems approach is designed to assess office workers' performance and effectiveness problems within technology intensive office work environments and provide realistic solutions for improving performance. The approach incorporates micro- and macroergonomic factors to adequately address the performance and stress and health-related problems associated with modern office work systems. The seven step approach consists of: defining the problems; setting the objectives and developing alternatives; modelling alternatives; evaluating alternatives; selecting an alternative; planning for implementation; and evaluation, feedback and modification. A detailed schematic presentation of these steps is provided. Solutions or alternatives are proposed to minimize the identified problem factors and to improve performance and the quality of work life.

1. Introduction

The traditional *microergonomic* approach to office work environments emphasizes microscale aspects of individual tasks and workstations (e.g. repetitiveness, design characteristics of the keyboard, screen and chair, etc.) (Cakir *et al.* 1978, Bradley 1989, Sauter *et al.* 1990, Kuorinka and Forcier 1995). However, the complexity of health and performance problems encountered in office work environments begs a systems approach. In such an approach, aspects of the physical environment (including work area layout, storage and adjustability) are combined with what are typically considered *macroergonomic* aspects of the job (work demands and pacing), the organizational setting (career path, shiftwork, job security), technology characteristics (computer interface design, automation) and psychosocial variables (job control, decision making latitude and participation) in the analysis (e.g. Smith and Sainfort 1989, Robertson and Rahimi 1990, Hendrick 1994, Karwowski 1994, O'Neill 1998, Swanson and Sauter 1999, Shoaf *et al.* 2000, Hendrick and Kleiner 2002). Understanding the interaction of these elements and their impact on worker health and organizational performance provides a necessary foundation for the identification and development of effective interventions.

With this type of approach, systems tools and processes can be used to develop strategic criteria for office work system design so that social and technical subsystems are congruent with the organizational mission. Directed by these strategic

* Author for correspondence. e-mail: michelle.robertson@libertymutual.com

Theoretical Issues in Ergonomics Science ISSN 1463–922X print/ISSN 1464–536X online
http://www.tandf.co.uk/journals
DOI 10.1080/1463922021000032320

level criteria, problem-solving tools such as ergonomic analysis of the job or workstation can better enhance organizational effectiveness. (e.g. Hendrick 1994, O'Neill 1998, Genaidy *et al.* 2002, Hendrick and Kleiner 2002).

Mosard (1982) proposed characteristics of a general framework for systems analysis. These characteristics included comprehensiveness, flexibility and clarity. He also proposed a seven stage general model of systems analysis that was heavily influenced by the earlier work of Hall (1969) on systems engineering morphology.

This paper describes the adaptation of the systems analysis model originally proposed by Mosard (1982) to ergonomic problem-solving in office environments. Coupled with findings derived from the broader micro- and macroergonomic literature, the approach aims to provide a framework for the systematic assessment of information on risks and potential solutions from ergonomics integrated with intra-organizational data on performance and health and safety (Liker *et al.* 1984, Robertson and Rahimi 1990, Bammer 1993, Kuorinka and Forcier 1995, Kleiner 1997, O'Neill 1998, Robertson 2001, Hendrick and Kleiner 2002).

The approach includes:

- identifying systems problems along with putative and ultimate causal factors,
- developing potential solution alternatives,
- evaluating the costs and benefits of these potential solutions,
- implementing the optimal solution or solutions, and
- providing feedback on the success of the selected solutions.

Those familiar with historical approaches to public policy decision-making (Quade 1982) and methods of graphical analysis in systems engineering (Konz 1987, Niebel and Freivalds 1999) will note similarities, as these disciplines all share a common systems ancestry to some extent.

2. A systems analysis approach

In the proposed systems analysis, the level of analysis is the business unit or department where specific objectives and issues are identified. Individual and group needs can also be identified. Contrasted with Mosard's original seven step model, the present authors have combined objective setting and alternatives development into a single step and have added a new final step—evaluation, feedback and modification process—to provide for feedback on intervention performance and for continuous improvement of interventions. The system analysis approach is presented schematically as follows:

(1) *The Problem Factor Tree* (PFT)—problem definition;
(2) *The Objectives/Activities Tree* (OAT)—objective setting and development of criteria and alternatives;
(3) *The Input–Output Flow Diagram*—alternatives modelling;
(4) *The Criteria Scorecard and Cost/Benefit Analysis*—alternatives evaluation;
(5) *The Decision Table of Future Conditions*—selection of alternatives;
(6) *Scheduling and Management of Project Flow*—implementation planning; and
(7) *Evaluation, feedback and modification process.*

2.1. *Step 1: Defining the problem—the problem factor tree*

From system performance data previously collected or recently observed, the PFT is constructed which identifies problems, sub-problems and potential causal factors, along with their interactions, in a logical, hierarchical structure. The PFT, originally proposed by Warfield (1977), could be considered a relative of the traditional cause-and-effect or fish diagram (Inoue and Riggs 1971). An important difference is that the PFT also presents the potential interactions between problem elements. Work issues and problems are precisely stated and linked together through an iterative process (Mosard 1982). Lower level causal factors in the tree contribute to the major problem.

A generic PFT is shown in figure 1. The major office work system problem is a composite of typical office work performance issues which are all hypothesized here: increased worker turnover, lost work days, claims and decreased performance and effectiveness. These performance issues are related to sub-optimal work system design and technology (Brill *et al.* 1984, Hedge *et al.* 1986, Taylor 1986, Hendrick 1987, Bongers *et al.* 1993, Kuorinka and Forcier 1995, Amick *et al.* 1999, Carayon *et al.* 1999). Psychological and physiological stressors are also potential contributing sub-problems (Smith and Carayon-Sainfort 1989, Hagberg *et al.* 1995, Carayon *et al.* 1996, Moon and Sauter 1996, Sauter and Swanson 1996, Schleifer and Ley 1996, Westgaard 1996).

Psychological stressors may be further sub-divided into psychosocial disturbances and perceived lack of environmental control (e.g. Karasek and Theorell 1990, O'Neill 1998, Moon and Sauter 1996, Robertson and O'Neill 1999). Closer examination of potential causal factors reveals more specific issues related to lack of job content, poor job design and lack of flexible workstation design (e.g. Moon and Sauter 1996, O'Neill 1998, Amick *et al.* 1999). These are depicted at the base of the tree. Job content and job design are the main elements of the social sub-system and several related individual and group level factors are further identified and shown in the middle of the tree. Suspect job design components may include teamwork or collaboration problems at the departmental level (such as cross-functional teams) or at the individual level (such as working pace).

Among many sub-problems identified within physiological stressors, two are particularly important: visual and musculoskeletal discomforts (Grieco *et al.* 1995). Screen design, workstation design, layout configuration of the workspace and flexibility issues contribute to both of these sub-problems (e.g. Cakir *et al.* 1978, Smith and Cohen 1997).

The problem factor tree integrates both *microergonomic* and *macroergonomic* aspects of office systems and sub-systems, including organizational and job design issues. This initial step of the systems analysis develops a better understanding of the technical, social and work environment sub-systems.

2.2. *Step 2: Setting the objectives and developing alternatives—the objectives/activities tree*

With the problem defined, objectives and evaluation criteria are developed for use in selecting the best alternative (intervention) to address the causal factors. The Objectives/Activities Tree (OAT) is a hierarchical, graphical depiction of objectives and solution alternatives developed to address the problems identified in the PFT (Mosard 1982). Mosard's OAT has some similarities to Hierarchial Task Analysis (Annett and Duncan 1967, Shepherd 2000), particularly in the specification of objectives/goals and actions/activities.

The tree is created by identifying a major goal, objective and sub-objectives. The upper half of figure 2 presents the major goal: 'To decrease turnover, lost work days

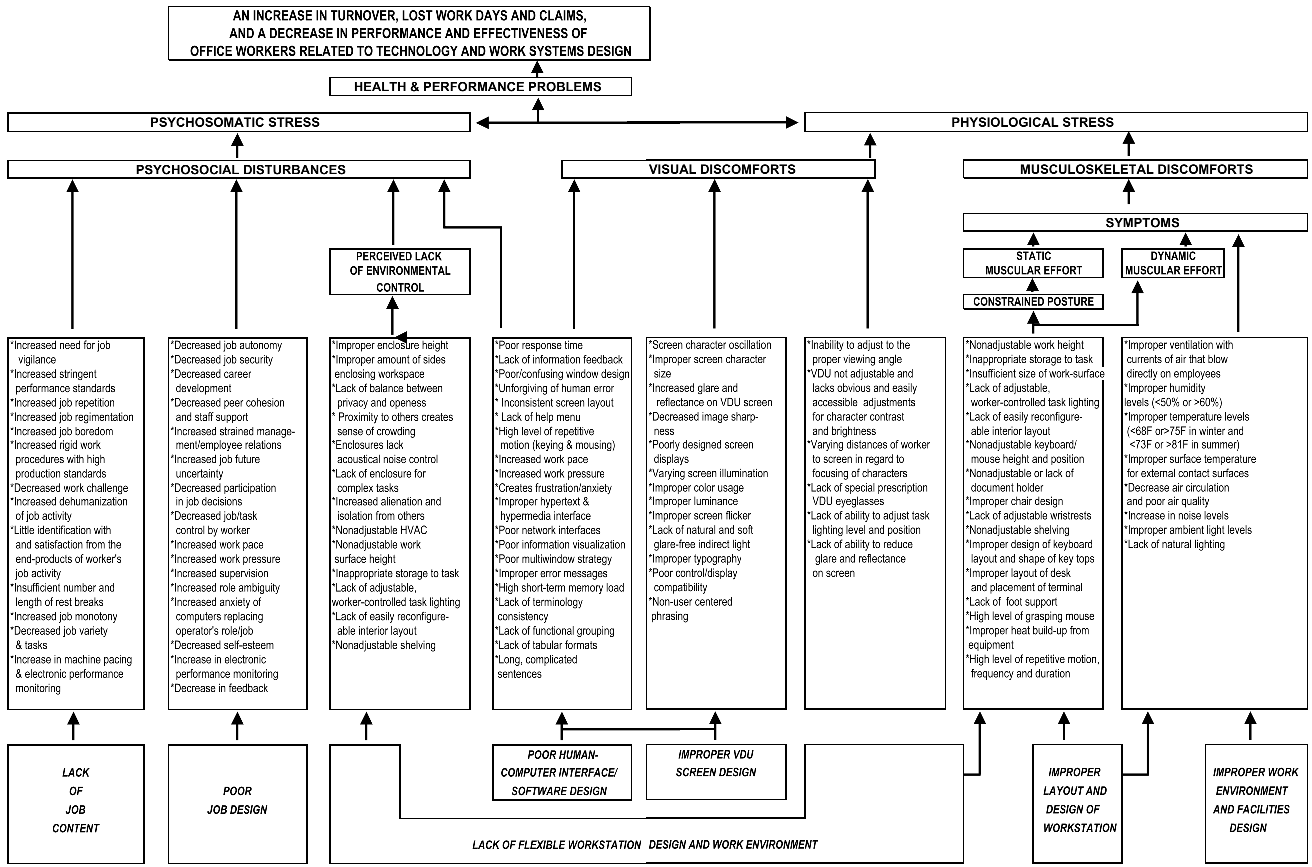

Figure 1. A problem factor tree (PFT) depicting micro- and macroergonomic sub-problems and associated factors in office work systems. The major problem is defined at the top with the sub-problems and associated factors shown below indicating the hierarchical, logical structure of the encompassing problem elements.

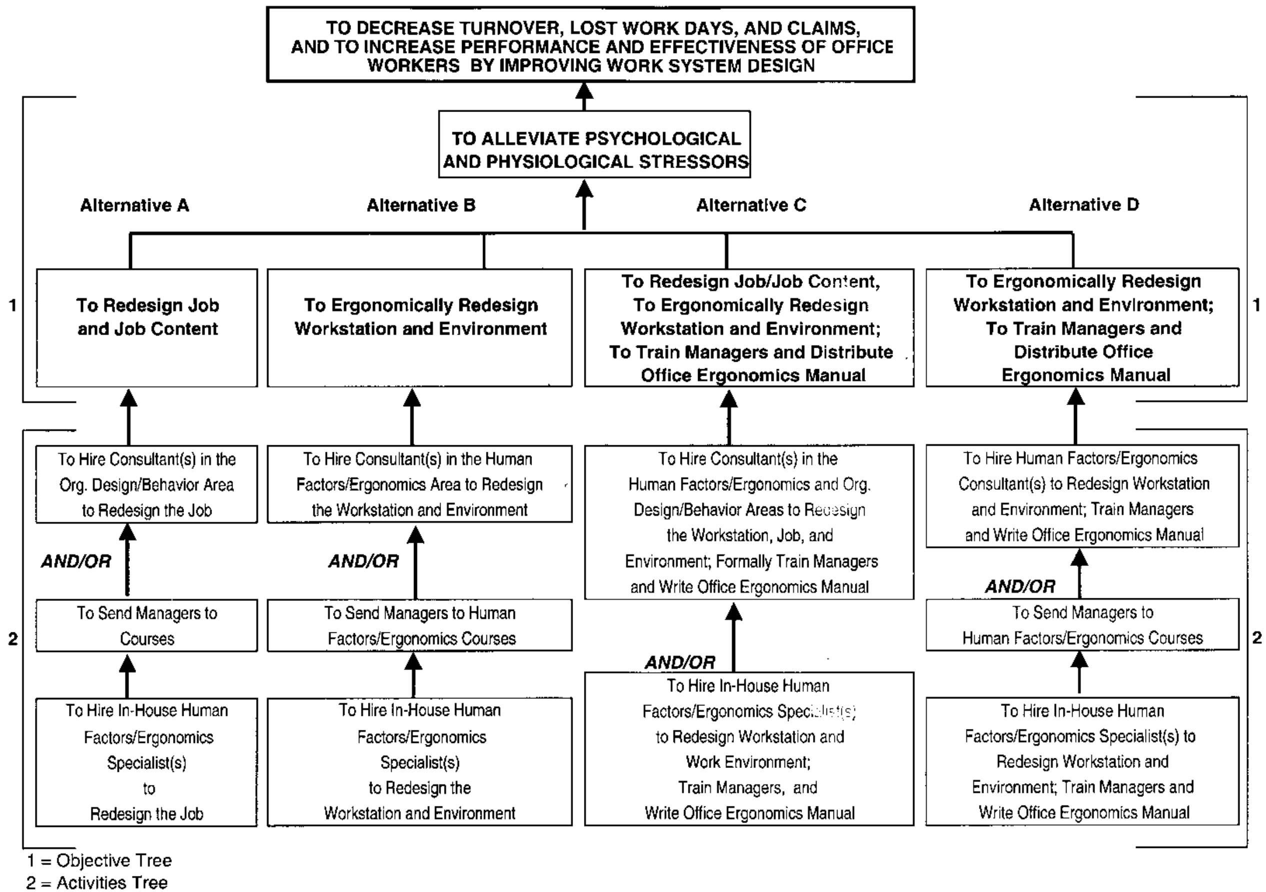

Figure 2. An objectives/activities tree illustrating four sets of alternatives/activities or organizational interventions for office work systems. The lower level objectives contribute to the attainment of the middle level objectives, which in turn contribute to the upper level needs or goals.

Table 1. A preliminary decision criteria which will be used in Step 4 to evaluate each alternative. Creating this table begins the process of identifying critical decision criteria.

Scope	Risk of failure (obstacles to success)	Costs: short and long-term	Benefits/Effectiveness
1. Will help the entire organization internally and externally	1. Employee's resistance to change	1. Materials and equipment	1. Increase in morale; quality of work life
2. Long-term programme effectiveness and efficiency	2. Employee's inability to learn new skills	2. Resources (physical and human)	2. Decrease in absenteeism (e.g. lost work days)
	3. Lack of management acceptance	3. Decrease in performance	3. Decrease in worker's compensation cases (medical related costs)
	4. Training programmes lag behind current knowledge	4. Ergonomic job design and training prgrammes	4. Increase in product quality; customer satisfaction
	5. Lack of active employee participation	5. Decrease in product quality	5. Increase in productivity
	6. Current job design inappropriate for new workplace designs	6. Production downtime	6. Decrease in turnover
	7. Stress from changes in the environment/technology/work organization		7. Decrease in job stress
	8. Fail to utilize traning manuals and materials		8. Increase in health and well-being
	9. Lack of management reinforcement and feedback		9. Decrease in number of claims
			10. Decrease in insurance costs
			11. Increase group collaboration

and workers' compensation claims and to increase performance and effectiveness of office workers by improving work system design and technologies'. The objective illustrated here is 'to reduce physiological and psychological stressors'.

Four potential solution alternatives along with a specified set of supporting activities are then identified to address the objective. Interactions between objectives and alternatives involved in the process should also be analysed (Mosard 1982).

The alternatives in the example include redesign of the job and job content (A), ergonomic redesign of the workstation and environment (B) and two hybrid alternatives incorporating one or more of these along with training and technology transfer components (C and D). Such hybrid alternatives may be created which incorporate the best features of any of the initially identified alternatives.

Several potential activities (action steps) are then proposed for each of the four alternative solutions (see lower half of figure 2). Solution alternatives and related activities are based on case studies, field research and longitudinal studies and represent typical approaches companies implement to achieve the major objective listed at the top of figure 2 (Smith and Carayon-Sainfort 1989, Sauter *et al.* 1990, Bongers *et al.* 1993, Bergvist *et al.* 1995, Carayon *et al.* 1996, O'Neill 1998, Bettendorf 1999). One of these solution alternatives will be selected in Step 5 and become the sub-objective in the objectives tree.

After the objectives and alternatives are selected, a preliminary decision criteria table is developed (table 1). This table is used to define the criteria on which the final selection decision will be made. Decision criteria typically include risks, costs, expected benefits and measure of effectiveness, based on both short-term and long-term perspective (Mosard 1982). These decision criteria should be considered as alternatives are modelled in Step 3. They also serve as the basis for the final decision criteria table, which is developed in Step 4.

2.3. *Modelling the alternatives—the input–output flow diagram*

In this step, each solution alternative and its associated activities are modelled to estimate the gross resource requirements and to assess its potential effectiveness. Typically, a descriptive or predictive model is used and the modelling techniques may include flow charts, simulations, etc.

Figure 3 presents a generic input–output flow diagram (IOFD) (Mosard 1982). The inputs to the diagram are the required resources that one can reasonably expect for the completion of a specified solution and set of activities. Resources include people, finances and information. Outputs are the results or products of the activities. In figure 3, some outputs become sources of inputs to other sub-systems, permitting a more complete representation of the entire system.

The IOFD is shown with two phases: a redesign phase and an operation phase. Inputs for the redesign phase include contributions from two general areas, human resources and financial resources. The human resources component may include individuals such as industrial psychologists, managers, employees, human resource managers, ergonomists, facility operations manager, trainers and health professionals. Outputs from the redesign phase become the inputs for the operation phase. For example, in the job redesign programme, managers and employees have acquired new skills and the jobs have been analysed and redesigned. In Phase 2, managers and employees interact within these redesigned work systems, and the results of these interactions are presented as final outputs (e.g. increases in performance, decreases in job stress, lost work days and workers' compensation

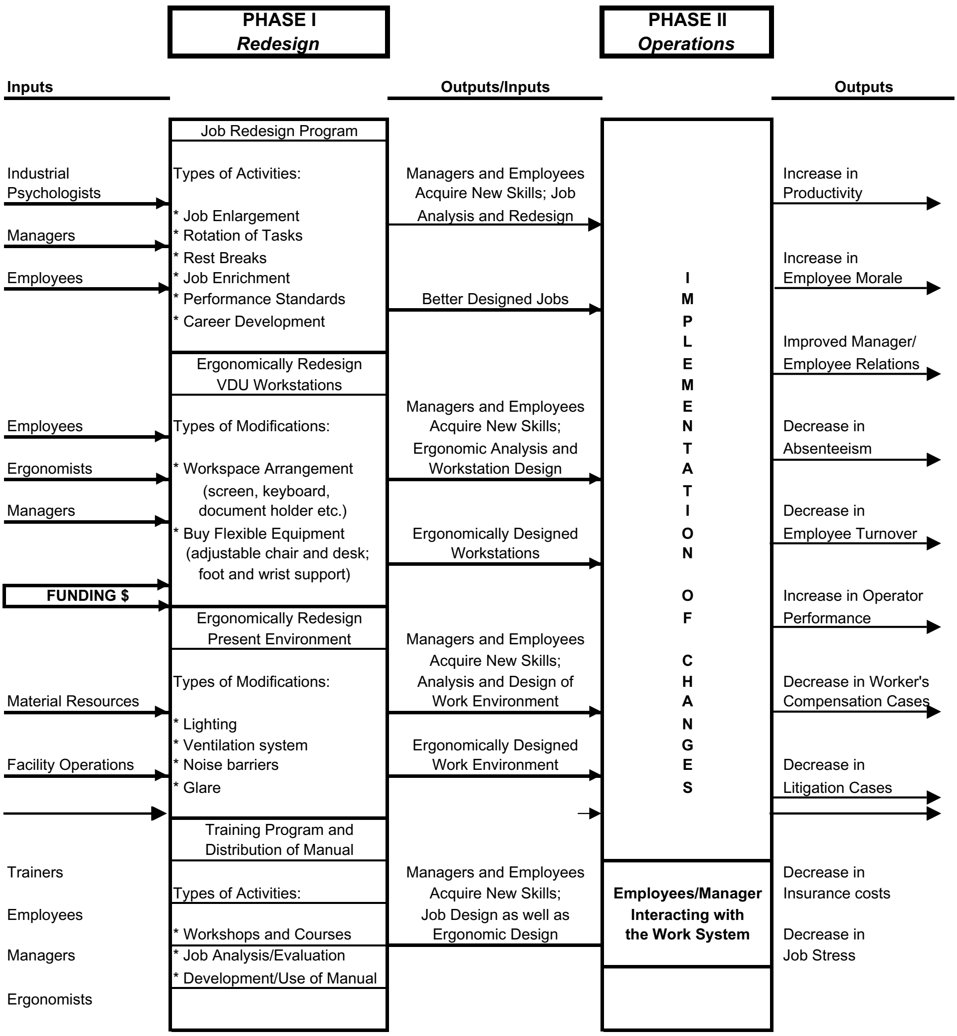

Figure 3. A model presenting an input–output flow diagram with two phases: a redesign phase and operations phase. This diagram depicts the office work systems alternative C, 'To redesign job/Job content, to ergonomically redesign workstation and environment; to train managers and distribute office ergonomics manual'.

cases). These outputs can be grouped into one of three categories: changes in employee and group behaviours, organizational factors and reductions in business cost.

2.4. *Step 4: Evaluating the alternatives—the criteria scorecard: economic advantage analysis*

Consistent with traditional multi-attribute valuation/utility and cost-benefit analysis approaches (Thompson 1980), each of the modelled alternatives and its associated set of activities is evaluated according to several major decision criteria. These criteria include project cost, risk of failure, potential effectiveness and benefits for all appropriate future conditions. The criteria may include both short- and long-term perspectives. Table 2 presents an example evaluation criteria scorecard for use in

Table 2. This evaluation criteria scorecard shows the economic advantage analysis of each office work systems alternative.

Alternatives[a]	Project cost[b]	Risk of failure	Effectiveness	Benefits[c]	Overall rating
Alternative A: Redesign job/job content	−3 ($175 000)	−2	+5	+6 (10%)	6 (moderate)
Alternative B: Ergonomically redesign workstation and environment	−4 ($370 000)	−3	+5	+6 (10%)	4 (moderate)
Alternative C: Redesign job/job content, ergonomically redesign workstation and environment, train managers and distribute manual	−8 ($590 000)	−1	+9	+9 (26%)	9 (high)
Alternative D: Ergonomically redesign workstation and environment, train managers and distribute manual	−6 ($440 000)	−2	+7	+8 (17%)	7 (moderate–high)

[a] In the four categories of Effectiveness, Risk of failure, Cost and Benefits, each alternative (A–D) was subjectively rated on a scale ranging from 0–10 or 0 to −10. Since Risk of failure and project costs are potentially negative characteristics, a rating scale was used ranging from 0 to −10. Effectiveness and Benefits are positive outcomes and, therefore, were rated on the 0–10 scale. The scores from each of the four categories were summed to determine the overall rating for each alternative. Along with the numerical ratings, table 2 shows subjective descriptors of the ratings in parentheses below each number of the 'Overall rating' column. Table 2 provides estimated project costs, anticipated net changes in employee productivity and descriptive labels for overall ratings in parentheses.

[b] Cost per 100 employees, in parentheses.

[c] Benefits are evaluated in terms of % increase in worker productivity in parentheses.

evaluating the four alternatives originally proposed in figure 2. For illustration purposes, each of the criteria are assigned equal weights, which are then summed across the four criteria to provide an overall rating. Weighted criteria may be assigned to each alternative as determined by the importance of each criteria.

The scorecard incorporates effectiveness and cost metrics including:

(1) *human resource costs*: compensation, salary, turnover, absenteeism, worker healthcare, wage replacement costs, other injury costs;
(2) *facilities costs*: rentable space, operating costs, annual facility costs, furniture investments, technology and information investments, work environment strategy costs, construction costs; and
(3) *effectiveness measures*:
   - organizational—process efficiency, work environment change, customer satisfaction, space utilization,
   - unit and departmental—product development time, successful projects, number of customers, and
   - group and individual—error rates, amount of completed work, quality.

Output from the analysis is expressed in terms of potential benefits of a particular alternative. It is typically expressed as a percentage of the annual investment in human resources demonstrated over 'X' years.

2.5. *Step 5: Selecting an alternative—the decision table*

Step 5 involves creating decision tables. Each decision table includes an assessment of the alternatives according to the probability of a future condition in the organizational environment. Table 3 provides a decision table using the available level of funding (or budget) as the future condition along with the expected probability of

Table 3. This decision table shows selecting an office work systems alternative based on future funding conditions.

Future conditions[a] (e.g. funding)	High level of funding	Moderate level of funding	Low level of funding
Probability of funding	0.50	0.65	0.80
Alternative A: Redesign job/job content	3	2	1
Alternative B: Ergonomically redesign workstation and environment	4	1	2
Alternative C: Redesign job/job content, ergonomically redesign workstation and environment; train managers and disribute office ergonomics manual	1	4	4
Alternative D: Ergonomically redesign workstation and environment; train managers and distribute office ergonomics manual	2	3	3

[a] The numbers indicate the selection preference rankings based on the probability assigned criteria and the overall rating scores for each alternatives from table 2.

that condition. Each alternative is then assessed against the level of the future condition (in this case high, medium or low available funds) and the probability of that level. For each future condition level, the analyst ranks each alternative indicating a first, second, third choice, etc. In table 3, when available funding is high, a more comprehensive and aggressive alternative is preferred; while, when funding is low, less ambitious approaches may be more realistic. The solution alternative which emerges at this point becomes the sub-objective in the Objectives/Activities Tree and proceeds to implementation.

2.6. *Step 6: Implementation*

A schedule and sequence of tasks, responsibilities and requirements is developed for implementation. This schedule may include a contingency plan with scheduled decision points and corresponding responsibilities. There are several available scheduling techniques that can be used as well as various software programs for creating new databases containing effectiveness measures, costs and other pertinent metrics collected during the systems analysis.

Figure 4 presents an implementation scheduling model, called a DELTA chart (Warfield 1971). The DELTA chart is a multipurpose flow chart that can be used to show aspects of major decisions (timing, responsibilities and choices), events (timing and duration) and activities (timing, duration and responsibilities) for the implementation of Alternative C. This chart provides an overview of plans for initiating and implementing the selected activities. This figure indicates specific requirements for the ergonomist and psychologist project leaders (PL). For example, the figure suggests that the ergonomist PL assign specialists in the team to assess and oversee redesign of workstations (chairs, computing equipment) and the office environment (lighting, acoustic isolation) in order to improve office-related task performance. The support of senior management is critical in the development of implementation models, especially where cross-functional cooperation is required. Implementation strategies incorporating multi-disciplinary approaches similar to the one pictured in figure 4 have proven successful in reducing psychological and physiological stressors associated with health and performance outcomes (NIOSH 1997).

Figure 4 presents the approach for an organization with significant expert personnel resources. While each of these aspects may well prove necessary in a specific application, not every organization may have the level of resources pictured here (e.g. not every organization will have industrial psychology and ergonomics personnel). Adaptive strategies for such organizations include collapsing these roles into existing personnel, seeking external expert assistance or a combination of these two approaches consistent with resource constraints.

2.7. *Step 7: Evaluation, modification and feedback*

Several activities occur in this step in order to define, establish and develop the evaluation processes. All of which provide feedback to the appropriate strategic decision-maker in the company regarding the results of the selected intervention alternatives, which comprise the micro- and macroergonomics programme components. Establishing an evaluation measurement process includes a five-step process as shown in table 4. This evaluation measurement model is commonly used by various companies and industries (e.g. Kirkpatrick 1975, Sweezy and Salas 1992, Gordon 1994, Ford *et al.* 1997, Oxenburgh 1997). A multi-disciplinary team consisting of various subject matter experts ensures a diversity of viewpoints and

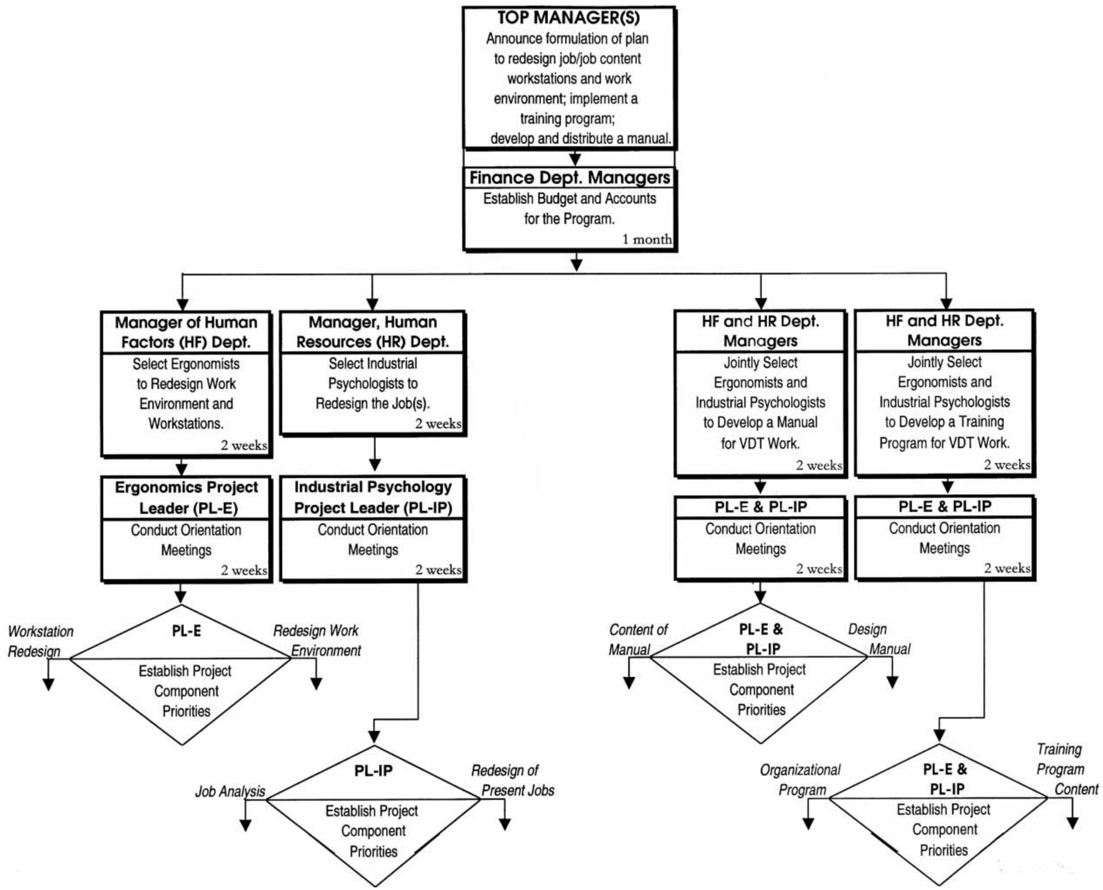

Figure 4. A DELTA chart for the implementation of Alternative C. This chart provides an overview of plans for initiating and implementing the selected activities.

Table 4. An evaluation measurement model with a five-level process.

Five level process	Examples of evaluation measures
1. Baseline assessment	Measurements taken prior to imprelementing the alternative (intervention). Measures could include: • Health and Safety Performance Indicators (e.g. lost work days, absenteeism, frequency and severity rates), • Productivity data (e.g. individual performance, strategic business units, organizational performance, market share, customer satisfaction, balance scorecard), • Users and managers current skills, knowledge, abilities, attitudes and opinions, and • Time series and trend data is perferred, several months to a year of data continuously collected before implementation of alternative.
2. Reaction	Users and managers reaction to the intervention; including managerial response. Measures could include: • Surveys (post-training), • Semi-structured interviews, and • User's perception of the usefulness and relevancy of the intervention to their job.
3. Learning	Users and managers degree of learning (knowledge, skills and abilities). Measures could include: • Surveys (pre- and post-knowledge tests), • Semi-structured interviews, and • Observations: attitude changes, opinions.
4. Performance	Users, managers and business unit performance. Measures could include: • Surveys: self-reported performance, perceptions, intent of behaviour changes, • Semi-structured interviews: Attitude, behaviour and productivity changes, • Observations: Behaviour changes, team performance changes (collaboration and communication), and • Unit or departmental performance measures (e.g. products, project completion, quantity and quality of service).
5. Organizational results	Performance and productivity measures. Measures could include, similar to baseline tracking measures: • Safety and Health performance measures (e.g. lost work days, frequency and severity rates), and • Strategic organizational performance measures (first to market, product innvovation, customer satisfaction).

critical inputs when developing evaluation measures for each of the five levels. Such a team may include people from human resources, finance, occupational health and safety, risk management, facilities, information services and engineering.

At each evaluation level, specific measures are defined. These measures may already exist in the organization, or they may be developed. Examples of some previously used evaluation measures are also given in table 4 (Gordon 1994). Using the evaluation process, the outcome measures that are most likely to reflect the impact of a selected alternative can be identified. This critical information can then be used to provide feedback to the programme team, an individual management decision maker or the organization as a whole.

Feedback regarding programme effectiveness begins the cycle of continuous improvement. Using information gathered from the evaluation and feedback process, the analyst can assess and then implement potential modifications and changes to the programme. This is the process of applying the systems analysis approach to solve problems and to measure the effectiveness of any selected alternative.

3. Conclusion

A systems analysis approach can enable an organization to better address micro- and macroergonomic factors which influence health and performance in the office environment. The traditional reductionist approach which focuses on interventions for the reduction of specific stressors has been widely applied. However, such an approach often fails to take into account the multivariate nature of today's health and performance problems and may produce less than optimal solutions. The systems approach described in this paper integrates micro- and macroergonomics aspects into an approach for solving office work systems problems. Organizations are allocating resources to office work systems problems in response to rising employment and benefit costs (e.g. O'Neill 1998, Levenstein 1999). The systems analysis approach can make an organization more competitive by improving the fit between the office worker, the job design and the physical environment, promoting a more healthful and effective work environment.

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About the authors

Michelle M. Roberston, PhD, CPE has conducted research projects in ergonomics and management for more than 15 years. Her research, primarily in office environments, focuses on work organization, work system design and culture, organizational ergonomics interventions, as well as training development and programme effectiveness. She has studied a variety of industries including telecommunications, aerospace, computer manufacturing and automotive. Prior to joining the Liberty Mutual Research Center for Safety and Health as

senior research associate in 1998, she was a senior research manager at Herman Miller, Inc., where she conducted research projects in ergonomics and organizational and individual effectiveness management and developed analytical tools and processes to help integrate organizational design and ergonomic solutions. She also spent 12 years at the University of Southern California where she served on the faculty at the Institute of Safety and Systems Management. She is a Board Certified Professional Ergonomist. She holds a PhD in Instructional Technology, an MS in Systems Management from the University of Southern California, Los Angeles, and a BA in Human Factors from the University of California, Santa Barbara. She currently serves as Secretary-Treasure-elect of the Human Factors and Ergonomics Society. She has published more than 75 papers and presented her work nationally and internationally.

Theodore (Ted) K. Courtney is Associate Director at the Liberty Mutual Research Center for Safety and Health in Hopkinton, MA. He is also Instructor on Injury, Safety and Ergonomics in the Department of Environmental Health at the Harvard School of Public Health and an affiliate faculty member of the Harvard Injury Control Research Center. At Liberty Mutual, he is responsible for global extramural research programmes and visiting faculty programmes. His research interests include ergonomics, epidemiology of injury, surveillance, musculoskeletal disorders and public health policy. At Harvard, he teaches in the occupational medicine and industrial hygiene graduate curricula, advises residents and collaborates on research and graduate programme development. He has been a member of the editorial board of the *American Industrial Hygiene Association Journal* since 1998 and has previously served as a guest editor with the *American Journal of Industrial Medicine* and *Ergonomics*. A board-certified safety professional, he was co-developer of the US national board examination in ergonomics for safety professionals. He is currently a member of the American Society of Safety Engineers Foundation Research Committee and previously served on national technical standards and advisory committees such as the ANSI-accredited Z365 Committee on Cumulative Trauma Disorder Control, the US Coast Guard's Partnership in Maritime Medicine and a variety of Special Emphasis Panels for the US Centers for Disease Control and Prevention. He was a President's Scholar at the Georgia Institute of Technology where he received his BS in Applied Psychology *summa cum laude* in 1987 and won the Moll Award for Excellence in Psychology. He received his MS in Industrial and Operations Engineering from the University of Michigan. He served on the faculty of the Georgia Tech Research Institute from 1989–1993 and received Outstanding Young Scientist and Program Development honours there. He joined Liberty Mutual as a Senior Research Associate in 1993. He is co-founder, strategist and research director of *JENS-Citizens for Safer Highways*, a non-governmental, community-based group that successfully campaigned for redesign of dangerous highways in Massachusetts. He served as a Baptist Disaster Relief worker in New York City immediately following the 9/11 terrorist incident.