Designation: E2350 – 07 (Reapproved 2013)$^{\varepsilon 1}$

Standard Guide for Integration of Ergonomics/Human Factors into New Occupational Systems[1]

This standard is issued under the fixed designation E2350; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Editorially corrected the Appendix in February 2015.

1. Scope

1.1 This guide is intended to assist in the integration of ergonomic principles into the design and planning of new occupational systems from the earliest design stages through implementation. Doing so may reduce or eliminate the necessity for later redesign that could have been foreseen.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions:*

2.1.1 *administrative controls, n*—work practices and policies that are implemented with the objective of enhancing human well-being and overall system performance through the way work is assigned or scheduled; examples may be found in Appendix X1.

2.1.2 *benchmarking, v*—identifying of best practices against which to compare the effectiveness of a process or design; examples may be found in Appendix X1.

2.1.3 *business outcome, n*—required products or services or both, that is, the desired and essential qualities and quantities of the end product of the occupational system.

2.1.4 *design team, n*—departments or individuals or both involved in or consulted during the design process including representatives of those who are involved or affected by the design; examples may be found in Appendix X1.

2.1.5 *engineering controls, n*—physical changes to jobs that are implemented with the objective of enhancing human well-being and overall system performance through the design and modification of the work equipment, facilities, or processes, or combinations thereof; examples may be found in Appendix X1.

2.1.6 *ergonomics/human factors, n*—scientific discipline concerned with the understanding of interactions among humans and other elements of a system and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance. (International Ergonomics Society)

2.1.7 *job, n*—set of tasks performed by one or more workers.

2.1.8 *knowledge base, n*—organized body of information applicable to the integration of ergonomics into new occupational systems including both general ergonomic resources, such as those found in the bibliography, and the experiences of the organization.

2.1.8.1 *general knowledge base, n*—ergonomic textbooks, guidelines, recommendations, reports of other companies' ergonomic programs, and so forth.

2.1.8.2 *internal knowledge base, n*—organized account of the organization's positive and negative experiences with occupational processes.

2.1.8.3 *project knowledge base, n*—working collection of experiences for the current project in which decisions made at each stage are added to the project knowledge base for use at later design stages, and after the completion of a project, the project knowledge base is integrated into the internal knowledge base.

2.1.9 *occupational ergonomic risk analysis, n*—occupational ergonomic risk analysis may include, but is not limited to, the evaluation of force (including dynamic motion), repetition, awkward or static postures, contact stress, vibration, and physiological and environmental factors such as temperature and other ambient air conditions and occupational ergonomic risks can be affected by workers' lifestyles and other nonoccupational risk elements.

[1] This guide is under the jurisdiction of ASTM Committee E34 on Occupational Health and Safety and is the direct responsibility of Subcommittee E34.80 on Industrial Heath.

Current edition approved July 1, 2013. Published July 2013. Originally approved in 2007. Last previous edition approved in 2007 as E2350 - 07. DOI: 10.1520/E2350-07R13E01.

2.1.10 *occupational system, n*—integrated collection of personnel, facilities, equipment, tools, raw materials, techniques, and other resources organized to produce a product or service.

2.1.11 *task, n*—group of related activities that comprises a component of a job.

2.1.12 *workers' capabilities and limitations, n*—those personal characteristics that workers bring to a job, such as:

Physical strength, endurance, agility, and skill and

Mental abilities, techniques, and knowledge developed through training, experience, and education. Examples may be found in Appendix X1.

3. Summary of Guide

3.1 This guide facilitates the integration of ergonomic principles into the design of occupational systems. It is assumed that there will be more than one iteration of the process, proceeding from the general and becoming more detailed with each iteration. The number of iterations will depend on the complexity of the process.

3.2 The evaluation begins by defining the business outcome, that is, the essential qualities and quantities of the end product or service.

3.3 After identifying the required process elements (physical and operational components), tasks are allocated to machines or workers.

3.4 The jobs are then analyzed to determine if they exceed worker capabilities and limitations.

3.5 Depending on the results of the analysis, the business outcome or jobs may be modified or action deferred to a later iteration.

3.6 Throughout the process, the knowledge gained is added to the knowledge base.

3.7 The operational audit evaluates the system as the design nears completion. It identifies and evaluates those issues either not considered or not apparent in previous stages. After the system is operational, periodic audits evaluate the effectiveness of the design.

4. Significance and Use

4.1 Integrating ergonomic principles into new occupational systems may help businesses develop processes that do not exceed worker capabilities and limitations.

4.2 Jobs and tasks that conform to worker capabilities and limitations may be performed more efficiently, safely, and consistently than those that do not.

4.3 The application of ergonomic principles to the processes involved in occupational systems may help avoid system failures and inefficiencies.

4.4 The integration of ergonomic principles at the earliest stages of process concept and design may facilitate appropriate design, layout, and allocation of resources and may reduce or eliminate the necessity for later redesign that could have been foreseen.

4.5 Designing jobs that fit the capabilities of larger population segments may increase an organization's accessibility to the available labor pool.

4.6 The integration of ergonomic principles into occupational systems may increase profit by lowering direct and indirect costs associated with preventable losses, injuries, and illnesses.

4.7 The bibliography contains a list of reference materials that may be useful in particular applications. All appendixes are nonmandatory.

5. Getting Started (see Fig. 1)

5.1 *Design Team*—Identify the departments or individuals or both who should be on the design team or consulted during the design process. They include representatives of those who are involved or affected by the design. Design team members may include representatives from engineering, labor, maintenance, marketing, vendors, safety and health professionals, and so forth, as appropriate.

5.2 *Allocate Responsibility*—Appoint members of the design team to be responsible for maintaining the knowledge bases, benchmarking, and the scheduling and performing of periodic audits.

5.3 *Business Outcome*—Determine the desired and essential attributes of the end product or service of the occupational system. The essential attributes of the end product or service determine what can and cannot be altered during the design process. They may include:

5.3.1 Manufacturing and assembly items,

5.3.2 Services to be provided,

5.3.3 Material to be delivered to the customer,

5.3.4 Specifications and acceptable tolerances,

5.3.5 Quality levels (allowable percentage of defects), and

5.3.6 The quantity of the product to be produced, including projections of future requirements.

5.4 *Knowledge Base*—Establish a knowledge base. Once a formal knowledge base exists, it will be used as a resource for the design project. Because experience gained during each project will be added to the knowledge base, it will grow and become essential to the design process. It includes the general, internal, and project knowledge bases. When first beginning to use this guide, it will be helpful to investigate similar occupational processes to see how problems were resolved and to identify experiences not added to the knowledge base. See Section 2 for more information.

5.5 *Benchmarking*—Identify benchmarks by which to judge the effectiveness of the process or design. Benchmarks may include cost per unit, downtime, absenteeism, turnover rate, workers' compensation costs, illness and injury experience, and delivery performance.

6. Evaluation of Process Elements

6.1 The evaluation of process elements is iterative (see Fig. 2). It begins with a broad identification of the issues and becomes more detailed with each iteration. Because each process is unique, this guide does not specify the number of

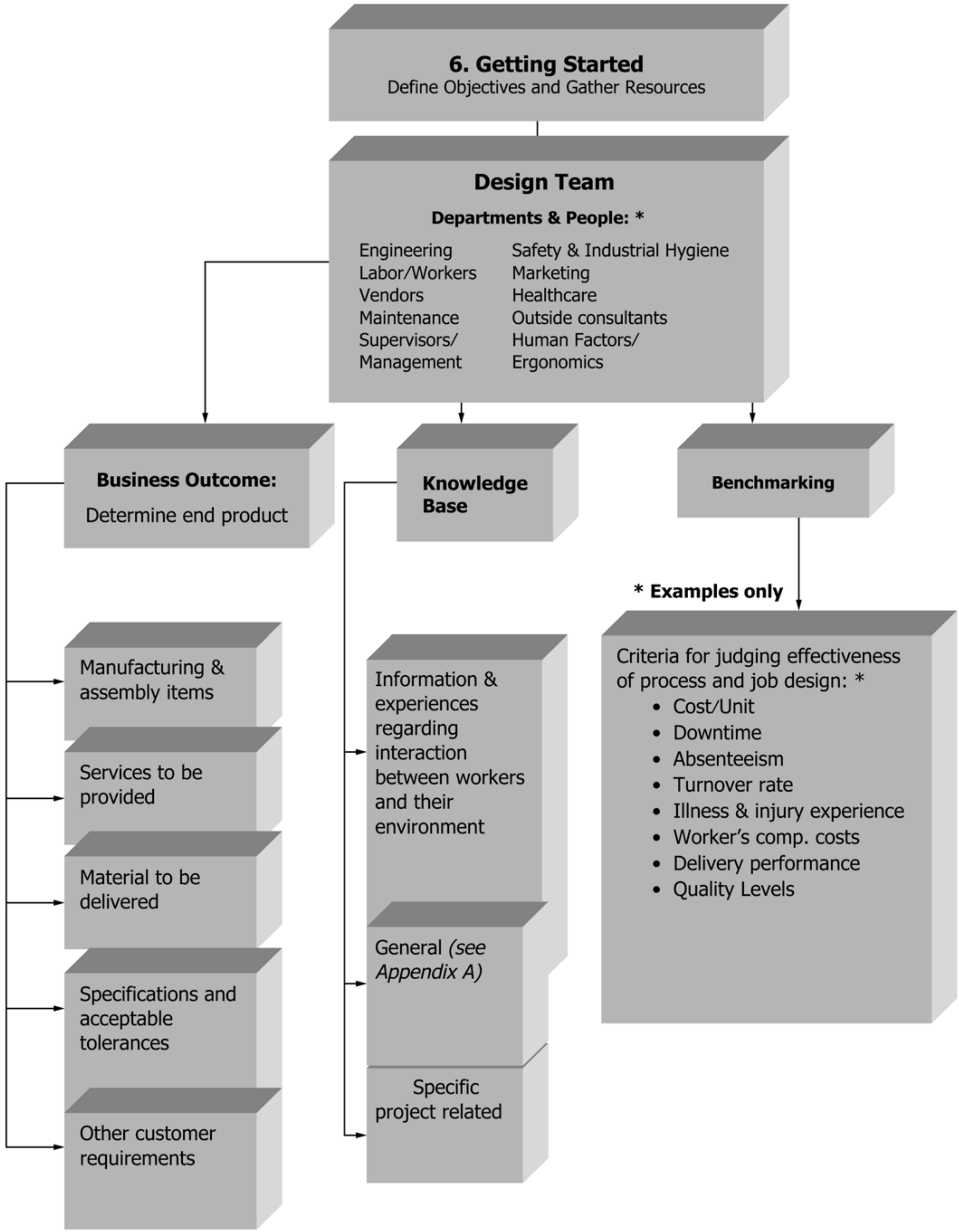

FIG. 1 Getting Started

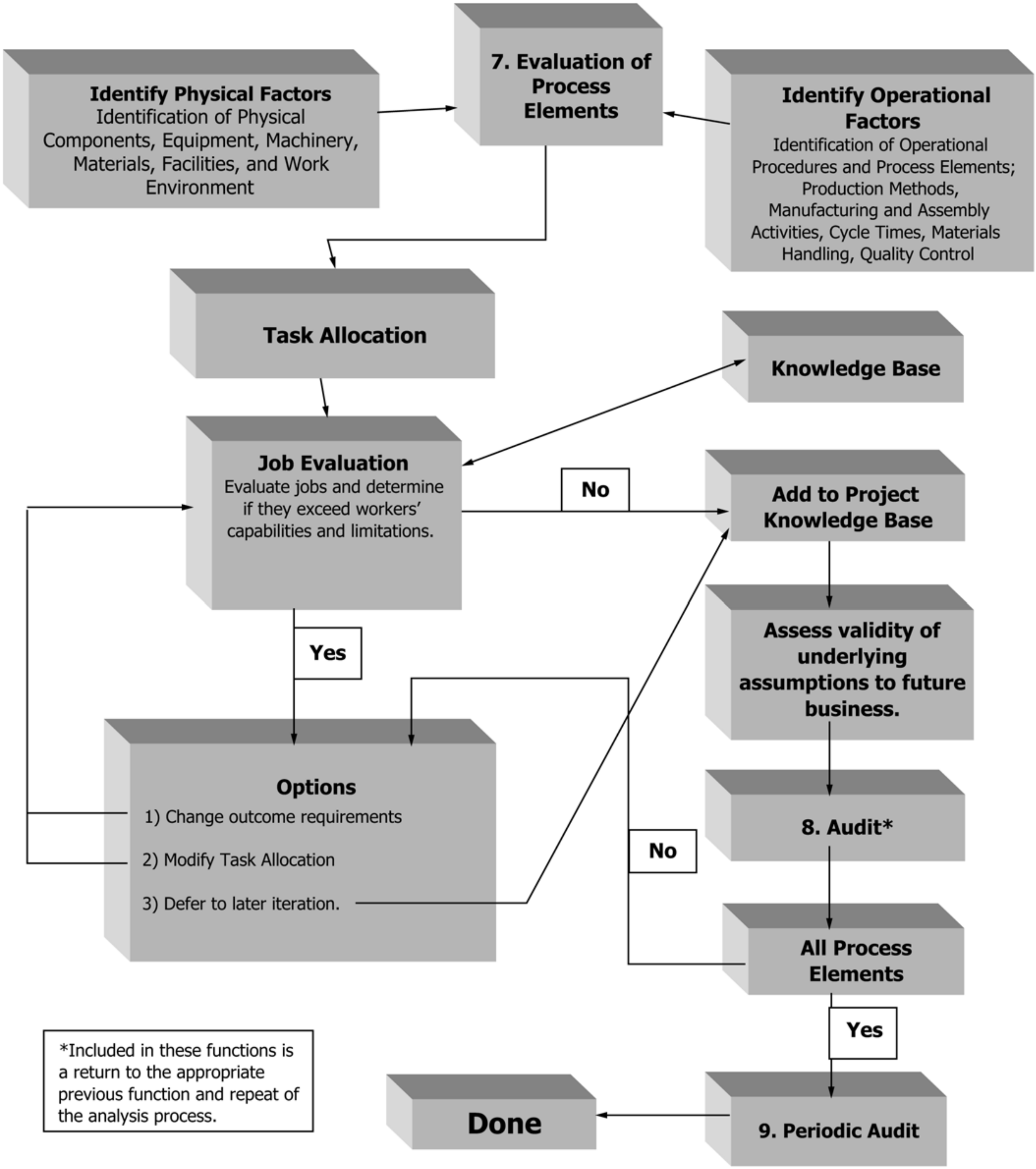

FIG. 2 Evaluation of Process Elements

iterations or what should be addressed in each iteration. Examples of issues to address may be found in Appendix X1.

6.1.1 *Identify Physical Components*—Identify equipment, machinery, materials, facilities, work environment, and so forth. Examples of elements to consider may be found in Appendix X1.

6.1.2 *Identify Operational Components*—Identify operational procedures and process elements: production methods, manufacturing and assembly activities, cycle times, materials handling, quality control, and so forth. Examples of elements to consider may be found in Appendix X1.

6.1.3 *Task Allocation*—Allocate tasks to workers or machines. This will be based primarily on the knowledge base, that is, experience with similar designs.

6.1.4 *Job Evaluation*—Determine the workforce capabilities and limitations that will be required by the process. Analyze the anticipated performance requirements of the processes. Evaluate the jobs and conduct an occupational ergonomic risk analysis. Examples of elements to consider may be found in Appendix X1.

6.1.4.1 *If worker capabilities or limitations are not exceeded*—Add the information to the project knowledge base and continue to the next level of evaluation.

6.1.4.2 *If worker capabilities or limitations are exceeded*—Modify the business outcome, task allocation, or add controls (engineering or administrative or both).

(1) Change the business outcome—It may be possible to modify the product or service as defined in the business outcome.

(2) Modify the task allocation—Review the task allocation and, if possible, modify those issues that have caused the conflict, including engineering or administrative controls or both or reallocation of tasks to machines. After modifying the task allocation, repeat the analysis.

(3) Defer action—If the task allocation cannot be altered, defer action to a later iteration.

6.1.4.3 *If no conclusion can be easily reached or if the extent of worker interaction has not yet been determined*—If there is insufficient knowledge or if the job demands appear to be close to performance limits, either modify the task allocation so that the requirements do not exceed worker capabilities and limitations, plan for controls at a later stage, or include other considerations that may help decide if changes are needed. In this event, several steps can be taken:

(1) Estimate the relative likelihood or severity of loss or failure.

(2) Determine if controls are feasible.

(3) Determine if controls can be added at a later stage in the process so that action is not required during this stage.

(4) Identify possible benefits of modification or change that could generate a value added return when combined with worker performance gains.

(5) Reexamine the business outcome.

(6) Assess validity of underlying assumptions to future business.

7. Audit

7.1 At the completion of the evaluation, perform an audit of the business outcome; all processes, steps, and activities; and task allocations. This check will help determine if earlier evaluations correctly identified and controlled the ergonomic issues. If decisions made in the evaluation of process elements result in jobs that exceed or might exceed workers' capabilities and limitations, the steps in Section 6 shall be repeated and appropriate corrections made.

7.1.1 *Operational and Physical Components Audit*—Does the project knowledge base identify any issues not addressed during earlier stages?

7.1.2 *Worker-Task Interaction Audit*—Have all jobs and tasks been evaluated for performance requirements and compared to the knowledge base?

7.1.2.1 *If worker capabilities or limitations are not exceeded*—Add this information to the project knowledge base, and complete the evaluation by scheduling a follow up audit.

7.1.2.2 *If worker capabilities or limitations are exceeded*—Make changes to bring performance within worker capabilities.

8. Periodic Audit

8.1 Schedule audits on a periodic basis.

8.2 Compare the performance of the system to the benchmarks established in 5.5.

8.3 Particular attention should be paid to monitoring those jobs or tasks where changes have resulted in conditions that may exceed workers' capabilities and limitations.

9. Keywords

9.1 ergonomics; human factors; occupational system; process design; work; work evaluation

APPENDIXES

(Nonmandatory Information)

X1. TERMINOLOGY EXAMPLES

X1.1 Benchmarks

X1.1.1 The following is a nonexclusive list of benchmarks that may be appropriate to consider in the implementation of this guide.

Cost per unit
Downtime
Absenteeism
Turnover rate
Delivery performance
Workers' compensation, illness and injury experience
Other

X1.1.2 *Design Team*

The following is a nonexclusive list of potential members of the design team.

engineering
human factors and ergonomics
labor/workers
maintenance
marketing
supervisors/managers
vendors
healthcare providers
other

X1.1.3 *Administrative Controls*

The following is a nonexclusive list of administrative controls that may be appropriate to consider in the implementation of the guideline.

employee rotation
job enlargement
employer-authorized changes in the pace of work
other

X1.1.4 *Engineering Controls*

The following is a nonexclusive list of engineering controls that may be appropriate to consider in the implementation of the guideline.

workstation modifications
changes to tools or equipment
facility redesigns
altering production processes
changing or modifying the materials used in the process
other

X1.1.5 *Operational and Physical Factors*

The following is a nonexclusive list of operational and physical factors that may be appropriate to consider in the implementation of this guide.

X1.1.5.1 *Physical Factors:*

product and subassembly quality issues and needs
production demands and production output needs
materials
equipment
space and storage requirements
product assembly or subassembly size, shape, and weight
physical components
forming equipment
fastening equipment
materials handling equipment
packaging equipment
assembly stations or lines
materials storage
work area layout and interface with other equipment, such as conveyors or other process machinery
forces anticipated in handling and assembly
walking/standing surfaces
clearances
process equipment
tools, tool design, tool specifications, and tool application
storage location, heights, depths
transport and materials movement equipment
weights and dimensions of incoming materials
weights and dimensions of completed products or subcomponents
lighting
heating
workstations
visual display terminals
seating
keyboards and other input devices
other

X1.1.5.2 *Operational Factors:*

raw material receiving
material handling
assembly activities
production methods
packaging and shipping
inspection and quality control
machine operation
transportation needs
work organization, including training and individual and supervisory responsibilities
basic cycle times
internal production and outsourcing of components
maintenance and repair requirements
work methods
material transport
work flow
force requirements
volume
staging of materials and equipment
process work methods
vibration

heat
cold
humidity
noise
other

X1.1.6 *Worker Capabilities and Limitation Factors*

The following is a nonexclusive list of worker capabilities and limitations that may be appropriate to consider in the implementation of the guideline.

information processing
strength
posture
postural stability
fatigue
repetitive motions
concentration
lifting abilities
lifting frequency
body size (anthropometry)
above shoulder activity
torso twisting
range of motion
standing
kneeling
vibration
clearances
visual acuity
hearing
health
reaction times
other

X2. EXAMPLES

X2.1 The following is a list of examples that may prove helpful in the implementation of this guide.

X2.1.1 The outcome of a new project is the production of a high-end network server. The assembled computer will weigh too much for a worker to lift and place in a carton repeatedly. That could be controlled with a change to the business outcome—it could either be redesigned to weigh less or manufactured in two parts, which could then be assembled by the user. However, both approaches are impractical. Instead, the issue could be handled at the process level by automating the packaging process or by using mechanical handling equipment on the production line.

X2.1.2 Demand for products increases dramatically throughout the year, often with very little advance notice. During those times, workers are put on extended overtime and required to work well above normal production levels. It is "common knowledge" that errors, damaged materials, shipping mistakes, injuries, and defective products increase during those times. By quantifying many of these costs and adding that information to the knowledge base, alternative cost-effective designs can be developed to accommodate higher capacities, such as adding temporary employees as needed or mechanizing some handling, thereby reducing those losses.

X2.1.3 Heavy bar stock, formally outsourced, will now be machined in house. While this is a physical element, the functional issues are also obvious. If the machining operation is performed manually, there will be a need to place each piece into a press manually, then remove the piece after the press cycles. Materials handling support with heat protection, personal protection equipment, and training, especially in high-production environments, will be needed.

X2.1.4 The pressroom given the task of handling heavy bar stock in X2.1.3 may choose to control the ergonomics issue by continuing to outsource the machining task. However, they could also decide to accept the work and add material handling controls at the process stage.

X2.1.5 In the previous example, the pressroom given the task of handling heavy bar stock decided to accept the work and to add material-handling controls at the process stage. These controls should be retrieved from the knowledge base and applied here.

X2.1.6 A computer system value-added reseller decides to offer on-site service for the computer hardware. While actual details of the service delivery are vague, from experience (the internal knowledge base), each service technician will have to carry a heavy toolbox, a laptop computer, and several large manuals. At this early stage it is clear that manual handling, in and out of the vehicle and the customer's premises, must be addressed.

X2.1.7 A telemarketing firm that contracts to do an opinion survey does not anticipate any change in the way that employees do their jobs. At this point, no issues would be evident.

X2.1.8 In X2.1.7, the new contract did not appear to introduce any new ergonomics issues since it would not fundamentally change the way that employees do their job. However, at the process stage, you learn that the customer has devised an exceptionally complex questionnaire that changes the questions and question sequence based on each response. This could affect error rate, cycle times, volume per person per day, and computer interaction issues.

X2.1.9 A work area designated for an inspection operation is large enough for ten inspection workstations. The business plan anticipates a production rate of 8000 parts per hour. However, the internal knowledge base shows that a per-person production higher than 750 parts per hour yields an unacceptably high error rate. There are many solutions to this problem, and the company may choose to take no action to reduce the quality risk. However, the opportunity to make changes early in the design phase has been identified.

X2.1.10 A preferred supplier offers raw materials in small bags. However, the anticipated volume would add to material-handling demands and labor costs. Process level controls can be used to accept 500-lb (227-kg) bulk loads, and the issue can be addressed at the process design stage.

X2.1.11 In X2.1.10, varying load volumes make the 500-lb (227-kg) bulk container impractical. Adding a second "floating" worker for the loading process, combined with a lift table, may provide an acceptable solution. In this situation, we have applied controls at three points: a change to smaller bags, a lift table, and the addition of a second worker.

X2.1.12 If the planned production rate of 8000 parts per hour in X2.1.9 cannot be supported by the current business climate, then it may be practical to postpone any action on inspection area redesign with the knowledge that an increase in production may also require additional capital costs for line expansion, including quality control.

X2.1.13 The process includes a computerized numerically controlled (CNC) machining center. We can anticipate that parts may be manually loaded and unloaded. The distance from the frame to the chuck may be of interest if part weight (a physical issue) is significant.

X2.1.14 Some components will be produced in house, others will be outsourced. Ergonomics issues involving handling, transportation, storage, loading, and management of these components should be included in this definition.

X2.1.15 A copier repair technician who cannot resolve the problem on-site must bring the equipment to a service facility. At this stage, we can anticipate ergonomics problems of handling and transportation of copiers by size and weight.

X2.1.16 A fast-food retailer offering "guaranteed delivery in 30 minutes" considers each delivery as a job cycle. By doing so, each of the elements that determine job cycle: travel distance, speed limits, anticipated traffic and traffic signal activity, accuracy of travel directions, and operator training can be included as ergonomic issues in the functional definition.

X2.1.17 A beverage bottling company plans to begin route delivery service to stores in remote areas not covered by other distributors. Many of the steps and activities, such as loading and unloading of vehicles and transportation of beverage containers from the delivery vehicle to the store can be anticipated at the preliminary design stage.

X2.1.18 In X2.1.17, beverage distribution methods can be expressed in very simple terms—"load vehicle," "drive to customer," "unload order," "place product on hand truck," "push hand truck into customer's store," "unload hand truck," and "return to vehicle." However, these general terms describe only general activities and do not provide the detail necessary to perform an ergonomics analysis. Information on weights, volumes, heights, methods, travel, and handling frequencies will all be needed to perform this analysis.

X2.1.19 As the design of a machining center is developed, increased part complexity now allows only 5 s for a worker to move from Machine A to Machine B to keep up with each machine's output. Unless these machines are directly adjacent, this rapid sequencing can become onerous. That can be avoided by moving steps and activities to either earlier or later processes. Controls could also be applied at the activity allocation stage by additional steps in the process or automating manual activities to give the worker more time between cycles.

X2.1.20 In the previous machining center example, the time available for the worker to move between Machines A and B per cycle could be expanded by activity reallocation. An automatic chuck could be added to one machine (allocated from worker to machine), and a deburring task could be reallocated to workers during a subsequent process.

X2.1.21 In X2.1.20, while the time available for the worker to move from Machine A to B per cycle was expanded with allocation changes, the difficulty in loading Machine A and a change in work area layout at installation has reduced this time back to 5 s. Workers are barely able to keep up with production, parts damage is much higher than expected, and workers have quit or posted to other positions in the plant. Changes in this job are indicated.

X2.1.22 Allocation of steps and activities may be described as "Lift 10-lb (4.5 kg) subassembly from pallet to bench once every 5 min" or "Retrieve customer order, ship date, price, and shipping charges within 20 s."

X2.1.23 An electronics company plans to manufacture and distribute network interface cards for retail sale. Although no decisions have been made about the manufacturing and assembly processes, the packaging subprocess will be similar to packaging tasks for the company's other products. An ergonomic evaluation of activity allocation can therefore be made at the preliminary design stage.

X2.1.24 A retail distribution center decided to use visual recognition of customer order numbers for processing of returns even though the combination of small character size and short processing cycle times increased the risk of miscoded merchandise. Four weeks after the operation began, an operational audit determined that the 2 % error rate was well within acceptable levels and chose to continue using visual recognition. A three-month follow-up audit was scheduled.

X2.1.25 Out-of-sequence production overloads the conveyors leading to packaging. The packaging workstations, designed for "one product at a time" packing, cannot accommodate more than two cartons. The result varies by workstation. Some employees are found packing multiple products using the floor for workspace, and others are walking to pick products manually off of the conveyor carrying them to the packing station. While there are many solutions to this problem, the ergonomic analysis at the audit stage will help identify these issues.

BIBLIOGRAPHY

(1) Alexander, D., *Ergonomics Design Guidelines*, Auburn Engineers Press, Auburn, AL, 1997.
(2) Alexander, D., *The Practice and Management of Industrial Ergonomics*, Prentice-Hall, Englewood Cliffs, NJ, 1986.
(3) *G-2001 Ergonomics Guideline for VDT (Visual Display Terminal) Furniture Used in Office Work Spaces*, Business and Institutional Manufacturers Association, Grand Rapids, MI, 2001.
(4) Booher, H. R., Ed., *MAN PRINT: An Approach to Systems Integration*, Van Nostrand, New York, 1990.
(5) Civilian American and European Surface Anthropometry Resource Project (CAESAR), Society of Automotive Engineers, Detroit, 2002.
(6) Corlett, E. N. and Clark, T. S., *The Ergonomics of Workspaces and Machines: A Design Manual*, 2nd ed., Taylor & Francis, London, 1995.
(7) Chaffin, D. B., Anderson, G. B. J., and Martin, B. J., *Occupational Biomechanics*, 3rd ed., John Wiley and Sons, 1999.
(8) Drury, C. and Czaja, S., *A Guide to the Ergonomics of Manufacturing*, Taylor & Francis, Philadelphia, 1995.
(9) Janowitz, I. and Thompson, D. A., "Ergonomics Programs," in *Occupational Health & Safety*, Balge and Krieger, Eds., National Safety Council, 2000.
(10) Karwowski, W., Ed., *International Encyclopedia of Ergonomics and Human Factors* (three volumes), Taylor & Francis, 2001.
(11) Kroemer, K. H. E. and Grandjean, E., *Fitting the Task to the Human*, 5th ed., Taylor & Francis, London, 1997.
(12) Kroemer, K. H. E., Kroemer, H. J., and Kroemer-Elbert, K. E., *Ergonomics: How to Design for Ease & Efficiency*, 2nd ed., Prentice-Hall, Englewood Cliffs, NJ, 2001.
(13) Konz, S. and Johnson, S., *Work Design: Industrial Ergonomics*, 5th ed., Holcomb-Hathaway, Scottsdale, AZ, 2000.
(14) Kuorinka, I. and Forcier, L., *Work-Related Musculoskeletal Disorders (WMSDs): a Reference Book for Prevention*, Taylor and Francis, Bristol, PA, 1995.
(15) Lim, K. Y. and Long, J., "The MUSE Method for Usability Engineering," Cambridge University Press, Cambridge, 1994.
(16) Lindqvist, B., *Ergonomic Tools in Our Time*, TR Tryck, Atlas Copco, Stockholm, 1986.
(17) Lueder, R. and Noro, K., *Hard Facts about Soft Machines: The Ergonomics of Seating*, London, 1994.
(18) MacLeod, D., *The Rules of Work: A Practical Engineering Guide to Ergonomics*, Taylor and Francis, New York, 2000.
(19) Mital, A., Nicholson, A. S., and Ayoub, M .M., *A Guide to Manual Materials Handling*, 2nd ed., Taylor and Francis, Bristol, PA, 1997.
(20) Mital, A., Kilbom, A., and Kumar, S., Eds., *Ergonomics Guidelines and Problem Solving*, Elsevier, Amsterdam, 1999.
(21) National Research Council Institute of Medicine, *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, DC, 2001.
(22) NIOSH, *Musculoskeletal Disorders and Workplace Factors*, U.S. Department of Health and Human Services, DHHS Publication No. 97-141, 1997.
(23) O'Brien, T. G. and Charlton, S. G., Eds., *Handbook of Human Factors Testing and Evaluation*, Lawrence Erlbaum, Mahwah, NJ, 1996.
(24) Pheasant, S., *Bodyspace: Anthropometry, Ergonomics and the Design of Work*, 2nd ed., Taylor & Francis, Philadelphia, 1996.
(25) Pulat, B. M. and Alexander, D.C., Eds., *Industrial Ergonomics, Case Studies*, Industrial Engineering and Management Press, Norcross, GA, 1991.
(26) Roebuck, J. A., *Anthropometric Methods: Designing to Fit the Human Body*, Human Factors and Ergonomics Society, Santa Monica, CA, 1995.
(27) Ryan, J. P., *Design of Warning Labels and Instructions*, Van Nostrand Reinhold, New York, 1991.
(28) Sanders, M. S. and McCormick, E. J., *Human Factors in Engineering and Design*, 7th ed., McGraw-Hill, New York, 1993.
(29) Salvendy, G., Ed., *Handbook of Human Factors*, 2nd ed., John Wiley & Sons, New York, 1997.
(30) Salvendy, G., Ed., *Handbook of Industrial Engineering: Technology and Operations Management*, 3rd ed., John Wiley & Sons, New York, 2001.
(31) Snook, S. H. and Ciriello, V. M., "The Design of Manual Handling Tasks: Revised Tables of Maximum Acceptable Weights and Forces," *Ergonomics* , Vol 34, No. 9, 1991, pp. 1197-1213.
(32) Stanton, N. and Young, M., *Guide to Methodology in Ergonomics*, Taylor & Francis, London and New York, 1999.
(33) Thompson, D. A. and Rempel, D., "Industrial Engineering and Ergonomics," in *Occupational Health & Safety*, 2nd ed., J. LaDou, Ed., National Safety Council, Itasca, IL, 1994.
(34) Wilson J. and Corlett, N., *Evaluation of Human Work-- A Practical Ergonomic Methodology*, 2nd ed., Taylor & Francis, Philadelphia, 1995.
(35) Woodson, W. E., Tillman, B., and Tillman, P., *Human Factors Design Handbook: Information and Guidelines for the Design of Systems: Facilities, Equipment and Products for Human Use*, McGraw-Hill, New York, 1991.