Final Performance Report
On-line Ergonomics Solutions for General Industry
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Abstract

This project created a website of over 1000 practical solutions for common causes of workplace Musculoskeletal Disorders (MSDs) in light manufacturing operations. These solutions were adapted from actual improvements in industrial settings that were made as a result of ergonomics consulting projects performed in over 1500 individual workplaces.

The goal of Phase I of the project was to develop a prototype website and then receive feedback from potential users on how best to structure the information to be easy to access and understand. Phase II of the project will be to add 4000 more solutions and to continue to study how to make the site as user-friendly as possible.

Phase I focused on Material Handling and Workstation Design in light manufacturing operations. Phase II will expand the topics to include Hand Tools, Maintenance, and Warehousing, along with other similar tasks in the service industry. In both phases, considerable emphasis is being placed on providing low-cost, low-tech solutions, including items that can be fabricated in-house.

There were two primary findings of the evaluations of the Phase I prototype:

(1) Users approach the internet search for ergonomics solutions differently, depending upon their background and experience. For example, manufacturing engineers are satisfied with skimming a long list of solution categories. However, plant nurses tend to approach the search more as a question, such as "How can I prevent back injuries." Consequently, in Phase II, new introductory portals will be added so that users with different styles of searching for information can access the solutions based on different frameworks and styles.

(2) The target users of this website were initially anticipated as occupational safety staff and production engineers in larger workplaces. However, the website is sufficiently down-to-earth that the target group can be expanded to small industrial operations without professional staff. Furthermore, as the site becomes more comprehensive, its value is rapidly growing beyond a website filled with ideas for preventing MSDs. In many ways, it provides a primer on how to set up a production operation intelligently.

MSDs continue to be a significant workplace problem, constituting about one-third of all injuries and about 70% of total workers' compensation costs. Furthermore, the same conditions that create the risk for MSDs also tend to increase time and effort, plus increase the risk of defects. As the solutions on this website show, the techniques that help prevent MSDs also constitute simply better ways of performing work

Cost-benefit studies were not part of this project. However, the solutions were developed in manufacturing plants where their implementation typically yielded cuts in workers' compensation costs by at least 50% plus increased productivity by roughly 10-15%.

The website can be accessed at: www.danmacleod.com/ergo/solutions.htm.

Section I — Highlights and Significance

Product

This project created a website of over 1000 practical solutions for common causes of workplace Musculoskeletal Disorders (MSDs) in light manufacturing operations. These solutions were adapted from actual improvements taken from the Principle Investigator's library of reports, photographs, and other information that have been accumulated in ergonomics consulting projects performed in more than 1500 individual workplaces.

The goal of Phase I of the project was to develop and evaluate a prototype website. The resulting prototype provides solutions in two primary topics: Material Handling and Workstation Design. These topics are in turn divided into a total of 33 categories and 185 sub-categories. Phase II of the project will be to add 4000 more solutions, expanded to include Hand Tools, Maintenance, and Warehousing, along with other equivalent tasks in the service industry.

The website places special emphasis on low-cost solutions, including items that can be fabricated in-house. Vendor information is also provided, either direct links to product websites that are especially useful, or general internet search categories or sources for commonly available items.

The site contains a basic tutorial on ergonomics as well as links to sources of additional books and training materials. The tutorial provides an introduction to the principles of ergonomics, an overview of ergonomics process (that is, the steps that need to be taken to implement a solution), and common errors in attempting to make improvements. The individual pages of solutions also provide background educational material. Thus, the site assumes low previous knowledge of the field and is designed to help non-professionals.

Comparison of Milestones

A comparison of the projected milestones from the grant proposal and actual milestones achieved shows the success of this project:

Goal	Actual
The prototype will be fully functioning and contain at least 200 solutions.	Fully functioning Contains 1000+ solutions
80% of the test subjects will be able to navigate the website	100% were able
The time requirements for finding a test solution will take at least 50% less time by using the website than without it.	Time saving were on the order of days to minutes, i.e. >99% time savings

The website is already in use by two Fortune 100 companies.

Findings

There were two levels of research for this project:

Data development — The research on effective solutions was conducted over a 30-year period as part of a private consulting practice. This research was not funded by the grant, but was essential to the project. Documentation of the effectiveness of the solutions was likewise not part of the grant, but examples are included in the tutorial under the title "Cost Reduction and Productivity Benefits."

Website usability research — A website of this nature and ultimate size can easily become unwieldy and difficult to navigate. Thus the research portion of this project is devoted to insuring that the site is as user-friendly as possible. The Phase I plan called for focusing on qualitative feedback from potential users and Phase II to address follow-up questions using greater emphasis on quantitative methods.

There were two primary findings of the evaluations of the Phase I prototype.

(1) Internet search behavior varies. The expectation was that users would search for solutions on the internet in a particular way, and that the website should be designed to match that pattern. However, the evaluations showed that different users approach a search differently, depending upon their background and experience. For example, manufacturing engineers are satisfied with skimming a long list of solution categories. However, a plant nurse tends to approach the search more as a question, such as "How can I prevent back injuries."

Furthermore, many users need assistance in understanding what they need. Common responses were: "How do I search for solutions that I don't know exist?" and "How do I know what I need to know?"

Consequently, in Phase II, new introductory portals will be added so that users with different styles of searching for information can access the solutions based on different frameworks and styles. The data base will still be developed based on solution categories and a robust search function will be added. However, the portals will provide access to the solutions based on problem statements such as, "What are effective ways to eliminate the need to lift?" and "How can we eliminate repetitive motions?" An example portal was created as part of Phase I entitled *How to Design a Workstation*, with step-by-step guidance that links to relevant solutions.

(2) The website has widespread general application. The target users of this website were initially anticipated as occupational safety staff and production engineers in larger workplaces. However, the Phase I evaluations showed that the site is down-to-earth, thus the target audience can be expanded to include small industrial operations without professional staff or previous exposure to ergonomics.

Furthermore, with new portals based on problem statements and the increasingly comprehensive list of solutions, the website can provide practical guidance to any

industrial user even if prevention of MSDs is not a conscious concern. For example, portals of the type *How to Set Up a Production Line* could potentially attract a large audience, especially in Phase III with an active marketing campaign.

Significance — $250 billion value

Work-related Musculoskeletal Disorders (MSDs) are the most prevalent, most expensive and most preventable workplace injuries in the country (OSHA, 1999). The U.S. Bureau of Labor Statistics (BLS) surveys show that MSDs comprise the single largest category of workplace illnesses and injuries, constituting one in three workplace injuries and illnesses. Furthermore, days lost related to MSDs are greater than other types of injuries, thus the costs of these disorders are greater than would be expected from the number of recorded cases (BLS, 2007). Workers' compensation costs to employers nationally total over $87 billion per year, an increase 36% since 2000 (NASI, 2006).

This website provides by far the largest, most comprehensive list of practical solutions available for general industry. There is no other equivalent source with the same depth and breadth of information that is simultaneously easy to understand and easily accessible.

The data base of solutions was developed in operations where their implementation typically yielded cuts in workers' compensation costs by at least 50% plus increased productivity by 10-15%. If U.S. manufacturing industry would systematically implement solutions described on this site, workers' compensation costs would drop on the order of $50 billion and manufacturing GDP would increase on the order of $200 billion.

Cost-benefit studies were not part of this project. However, a review of case examples from the PI's consulting projects is provided in the tutorial. These examples also serve as documentation for the statements above.

Section II — Scientific Report

Background for the project

The Principle Investigator (PI) is president of an ergonomics consulting firm that specializes in working with employers in general industry to identify practical solutions that reduce the risk of workplace Musculoskeletal Disorders (MSDs).[*] The company maintains a large library of reports, photographs, video clips, and related information on feasible methods to reduce MSD risk factors compiled from ergonomics evaluations over a 30-year period in more than 1500 individual workplaces. The project was designed to convert this information into a website of ergonomics solutions for common tasks in general industry that create risks for MSDs.

As described in the Phase I grant proposal, the scientific basis of the risk factors of MSD risk factors is well-established in the literature (NIOSH, 1997; NAS, 2001). The solutions in the website provide numerous techniques for reducing these risk factors. For example, the harmful effect of working with a bent posture of the lower back has been well established and accepted, including quantitative guidelines and models (e.g. NIOSH, 1994; Chaffin and Andersson, 1999). The website provides hundreds of techniques to improve lower back posture for various common tasks in general industry.

Documentation of past successes in reducing risk factors based on these techniques was not part of this grant project. Nonetheless, examples of successes were included in the tutorial under the title *Cost Reduction and Productivity Benefits.* Furthermore, the relationships between the solutions and the risk factors are generally evident and intuitive. It should also be noted that the extent to which the techniques on the website can reduce risk depends on the circumstances in each workplace situation.

Specific aims

The Phase I plan was to develop a prototype website of practical solutions, initially focusing on light manufacturing. The objective for the prototype was to develop an easy-to-use framework that would be expanded to other industries and occupations in Phase II.

The target users of this website were production engineers and occupational safety and health staff from workplaces in industries that involve high risk for MSDs. Since at least some of these users could be expected to have minimal previous exposure to the contents, the website needed to be educational, with no assumptions made about a high level of prior knowledge.

The data base files were to include an array of possible options for each workplace problem, with pros, cons, and possible pitfalls of these various options. The data files were intended to provide enough background information to provide users with context to

[*] A general class of conditions that involve the nerves, tendons, muscles, and supporting structures of the body. Risk factors include awkward postures, excessive force, repetitive motions, static load, and vibration.

understand the application of the solutions. Links to vendors were to be included as applicable, along with photographs and illustrations of the solutions in actual workplaces.

The plan for the prototype also included a tutorial to provide users with background information on ergonomics and the practical application of the solutions on the site and possible unintended consequences. The tutorial includes links to additional support materials, such as books, training videotapes, and analytic tools. Thus, the website would constitute a component of a larger package of support.

The Phase I proposal listed the following anticipated tasks:

1. Develop the prototype
   a. Solution files
   b. Website
2. Assess taxonomy questions
3. Conduct usability testing
4. Conduct time study

Development of the prototype

All of these specific aims were fulfilled in the prototype. A comparison of the projected milestones from the grant proposal and actual milestones achieved shows the success of this project:

Goal	Actual
The prototype will be fully functioning and contain at least 200 solutions.	Fully functioning Contains 1000+ solutions
80% of the test subjects will be able to navigate the website	100% were able
The time requirements for finding a test solution will take at least 50% less time by using the website than without it.	Time saving were on the order of days to minutes, i.e. >99% time savings

The website can be accessed by reviewers for direct evaluation: www.danmacleod.com/ergo/solutions.htm.

Data base

The solutions in the prototype focus on two broad topics in light manufacturing: Material Handling and Workstation Design. Each of these topics is divided into categories and subcategories of solutions, along with one or more examples each, illustrated with photographs and, in a few cases, with video clips. At present, each category is a separate webpage and the subcategories are sections of that page. The specific categories are shown in Appendix A or viewed on-line.

The website lists 15 categories of Material Handling, divided into about 85 subcategories. Workstation Design includes 18 categories and about 100 subcategories. The total

number of solutions exceeds 1000. Printed out as hard copy, the entire website numbers 310 pages, that is, the equivalent a full-length book.*

The categories of solutions for each of the two main topics are comprehensive; that is, there are no major gaps in the knowledge base. To be sure, it is possible to add more specific examples and perhaps divide or combine some of the categories, but the data base provides a rather complete description of solution strategies.

The website places special emphasis on low-cost solutions, including items that can be fabricated in house. Vendor information is also provided, either (1) direct links to product websites that are especially useful, or (2) general internet search categories or sources for commonly available items.

A working title of "5000 Ergonomics Solutions" was chosen for the website to signal to users that the site is substantial and contains a wide range of solutions.

The prototype is sufficiently developed that by the end of Phase I, it is already in use by two Fortune 100 manufacturing companies.

Phase II will be to expand the solutions to include the service industry and other high risk occupational categories:

- More topics, such as: Hand tools, Maintenance, Warehousing, Delivery,
- Additional specific tasks: hanging/unhanging paint lines, loading hoppers, loading/unloading trucks
- More subcategories to existing categories: e.g. add Manipulator arms to Material Handling
- More examples throughout.

Potential Misinterpretations

In authoring the solution files, great care was taken to prevent misinterpretation of the information. The developers' biggest concern that a user would over-interpret the implications of a particular solution, that is, believe that the solution was "ergonomic" and therefore a perfect practice that would guarantee a reduction in injuries regardless of the specific situation.

Steps taken to help prevent misapplication included the following:

- The array of solutions provided for each issue inherently shows that there is not just one solution, but multiple options to select from to fit specific needs.
- Each webpage of solutions refers to the underlying principles and objectives to keep in mind while considering the specific solutions.

* The value of the internet compared to the printed page for this project is evident. This website provides ability to update quickly and to expand the information without limits. The printed page would be unwieldy for this purpose.

- Most pages include pros and cons and common pitfalls regarding various solutions. (Additional information of this sort will continue to be added as opportunities are noted.)
- Cautionary wording was used as much as possible. For example, instead of implying that a particular action *must* be taken, the wording was selected along the lines of "*usually* in these situations" or "the *typical* steps." Similarly, wording was selected to avoid inadvertent guarantees that a particular solution would always work or automatically reduce injuries.
- The introductory section "About this Site" contains a separate page on "Cautions" that addresses interpretations.
- Likewise, the Tutorial contains a separate page "Common Errors."

Lessons learned in developing the data files

The development of the solution files occurred as expected, with two exceptions:

1. Photographs — Photos that are satisfactory for use in PowerPoint presentation or in a written report often cannot be used on a website without photo editing to remove extraneous equipment that distracts from the point of the photo. In presentations using PowerPoint, a speaker can point out the solution, but in a stand-alone photo, it can be difficult to distinguish one thing from another. Photo editing is time-consuming and the process required an unexpected amount of time and effort.

2. Data base search function — The original plan for Phase I was to incorporate robust search capabilities for this data base. However, in the process of creating the prototype, the developers realized that data base software is difficult to edit compared to page authoring software. The decision was made to develop the site as using page authoring software and convert to data base software as part of Phase II.

Procedures and methodology

The Phase I research objective was to evaluate the efficacy and usability of the prototype ergonomics website. Core research questions were:

- Does the website contain useful information?
- Are topics and results easily found within the website?
- Is this website more effective than current alternatives for finding possible engineering controls for MSDs?

The Phase I plan called for focusing on qualitative feedback from potential users and Phase II to address follow-up questions using greater emphasis on quantitative methods.

Phase I usability research was based on focus groups consisting of users from the target audience, i.e., manufacturing personnel such as safety managers and engineers. A total of 9 focus groups were held involving a total of 48 subjects. Demographic information is summarized in Appendix B.

As planned, the focus group sessions were held in conjunction with training and problem-solving sessions during the PI's consulting projects on site in manufacturing locations. An unanticipated benefit of this format was that website research questions were directly related to each worksite and its MSD problems. As a result, the focus group discussions had a very pragmatic orientation related to the participants' own needs.

The general research and development plan was iterative, that is, to develop a section or feature of prototype and then involve focus groups to provide immediate feedback. Thus, a design issue was tested in several rounds and changes made based on results, then tested again.

As noted in the Phase I proposal, usability testing often involves using small sample sizes, since the goal is to observe behavior in qualitative terms, rather than obtain statistically significant measurements. Recent experience shows that a very small group, such as four or five test subjects, provides equally useful feedback as larger groups (Krug, 2006; HHS, 2007; EU, 2007).

As described below, these focus groups provided extremely helpful information. Indeed the initial groups led to major changes in the plan for the website.

Results and discussion

Internet Search and Browsing Behaviors

The initial topic for the focus groups was to understand how users normally search for ergonomics solutions. The discussion yielded several major insights (dramatically emphasizing the importance of involving users in the design of any product):

- The initial expectation was that there would be a standard search method that users employ when looking for an ergonomic solution on the internet. The focus groups quickly revealed that multiple search strategies are used, based on an individual's background and experience.

- The primary problem in current use of the internet is that most users don't know what types of solutions are available and don't know what exactly to search for. One focus group participant stated "How do I know what I need to know? How can I search for something that I don't know exists?"

- Many users tend to search for information based on a problem statement rather than by solution topic, e.g. "How do I eliminate back injuries from lifting" (the problem) rather than "types of conveyors" (a solution).

- Search inquiries tend to be vague: "How do I prevent repetitive motion disorders" or simply "ergonomic tools."

- Engineers tended to be comfortable with browsing lists of solutions ("conveyors." "hoists," or "tilters"), but many health and safety professionals tend to search from the perspective of injuries ("how to prevent back injuries").

- The focus groups greatly appreciated the approach used in the prototype solution files of listing multiple options and photos. They emphasized the need to be able quickly skim the various categories and see what might apply to them, thus learning of techniques that were unknown to them.

These findings changed this project in several important ways:

1. The thrust of Phase I was altered to expand the number of solutions provided in the prototype so that the information would be more comprehensive, listing as many categories of solutions as possible. The original plan was for 200 solutions in several topic areas, which was changed to 1000 solutions in just two topic areas (Material Handling and Workstation Design).

2. The Tutorial section on "Principles of Ergonomics" was edited to add links to solution files based on the principle affected. Thus, this training document was adapted to serve as a portal of its own to the data base.

3. A new introductory portal "How to Design a Workstation" was created that leads into the data base in a step-by-step sequence. Thus, this page serves a critical educational purpose while simultaneously providing a portal to the categories of solutions.

4. The plan for Phase II was altered to provide multiple perspectives for browsing the data. The original plan was solely to use the solution topics and categories, as shown in Appendix A. The plan now involves providing options for browsing by a problem statement:

    - Basic "how to's"
        - How to design a workstation (completed)
        - How to set up a production line
        - How to improve manual material handling
        - How to find or create ergonomic hand tools

    - Generic problems
        - Lifting
        - Push, Pull, Carry
        - Repetitive motions

    - Injury prevention
        - Back injuries
        - Shoulder and elbow problems
        - Wrist disorders

The home page was modified to incorporate this need to provide for multiple perspectives, indicating the sections completed as part of Phase I and the sections to be added in Phase II.

As a final note, the focus group evaluations led to the understanding that there are not one, but two levels of searches: (1) Finding this site on the internet, and (2) Navigating within the site. Finding the site may be a matter of tagging the site to be picked up by search engines, along with marketing exposure. Navigating within the site is the subject of usability research.

Taxonomy

The focus group insights on search and browsing behaviors affected the evaluation of taxonomy questions. The prior expectation was that organizing the solution files into intuitive browsable categories would be a key issue. The plan was to uncover how users expect to have solution categories displayed and thus help ensure that users find the information they needed once they entered the site. Similarly, a prior expectation was that it would be important to find the most logical or commonly used terms for various common types of ergonomic equipment.

However, as noted above, many users search by problem statement rather than by solution categories. Thus, the taxonomy questions have become less important.

Additional insights provided by the focus groups were:

- Users who are highly experienced in manufacturing operations understand that the solutions can be categorized in different ways and that terminology varies considerably. Thus, the terms and categories do not matter that much to this group — they quickly understand what solutions are available in which pages.

- Users less experienced in manufacturing do not have expectations for terms of categories or terminology. The bigger barrier is that they simply don't know what they're looking for.

- Some common ergonomic devices have no preferred terms whatsoever. An example is a new and increasingly common type of lifting device that can either be classified as a cart or as a pallet lift. There is no standardized name for this device, consequently the developers resolved the dilemma by making it a separate category and using the descriptive, if clumsy, name of "Lifter-Transporter."

- Photographs may be more important than terminology. Users find it helpful to see various devices.

Consequently, the more formal evaluation techniques that were planned for Phase I, such as card sorting, proved unnecessary. Focus group comments were helpful in some cases for settling on a particular categories and terms. But the primary consideration ended up

being the categories that seemed logical to the developers as the solutions were assembled. In several cases, the number of specific techniques in a given solution category became unwieldy and led to subdividing and creating new categories.

It should also be noted that once the new entry points for browsing by problem statement are developed in Phase II, the need for precise terms and categories of solutions becomes even less important. Additionally, the robust search function and keyword system planned for Phase II reduces the need for taxonomy research. Users should be able to find good solutions no matter what search words or browsing strategy they use.

Two additional comments are pertinent:

- In the process of developing the prototype website, the PI reviewed the solution categories used by various industrial suppliers in their respective websites. The conclusion is that there is not much consistency in taxonomy, but it does not appear to be a barrier. Users of industrial supply sites apparently are knowledgeable enough to recognize the right categories for what they are seeking.

- Focus groups were satisfied with the framework currently in use on the website. In the words of one participant, "It's logical, understandable, and as good as any."

In sum, identifying optimal categories for ergonomics solutions is not as important as providing easy ways for users to skim the categories to see what might work for their needs. These findings supported those of search behaviors described above. The goals of Phase I were better served by expanding the number of solutions rather than testing taxonomy.

Time Study

The Phase I research plan called for a time study to compare the length of time needed to find the information on the regular internet versus the prototype website. Several individuals were shown a photograph of a solution and asked to search for it on the internet.

The test was found to be senseless, since many users didn't know where to begin on the internet, or after five or ten minutes searching, it was clear that time was being wasted in the effort. As one individual stated, "The issue isn't how fast I can find something on the internet. The issue is that I don't know what to even look for." In contrast, the same individuals found the information on the prototype website almost immediately.

Spontaneous comments during the focus group sessions provided equivalent data. One participant volunteered that on the prototype website he "found in minutes information that had previously taken days."

It may be that a time study comparing the prototype website with a standard internet search is not a fair test, since the prototype website is dedicated to the topic. Once a user

is on the website, it is too easy to scan the list of solutions and find likely category and then the solution.

All (100%) of the focus group participants were easily able to find their way on the prototype and identify solutions to problems, indicating that the project is on a good path.

Perhaps as the site gets larger, navigation may become more of a problem. The Phase I prototype may simply be too small, even with 1000 solutions. Furthermore, providing multiple entry points for browsing adds complexity and possible confusion. Thus there is a need to continue to investigate usability.

Tutorial

Several focus groups were asked to evaluate the tutorial. However, these individuals (as with all of those involved in the focus groups) were fairly experienced with ergonomics and the common pitfalls of implementing solutions. The response was generally that it was good to provide the tutorial, but their interest was low.

Consequently, the Phase II plan should involve more novice users in the usability studies, e.g., personnel in small manufacturing operations who are neither engineers nor safety and health professionals.

Photos

The focus groups were all very positive about the use of photos on the site, generally urging "the more the better." There was a strong preference for actual workplace photos to drawings or other types of images.

"Use as many photographs as possible to deal with the problem that we don't know what to call things."

Vendor information and credibility

Focus groups were asked about providing links to specific vendors on the appropriate solution pages. This topic was closely related to that of overall credibility of the site.

One focus group participant followed up the session with an email, which summarizes the typical response: "The information is very helpful because I know it offers a variety of solutions based on needs (from an ergonomics viewpoint), not based on what's available (from a salesman's standpoint). Credibility of the site goes up knowing the purpose of the site and that it's not a sales site."

There was consensus that it is good to having vendor information listed, including direct links to vendor websites, since it saves the users' time. However, they want reassurance that there is no hidden financial relationship.

Providing information on low cost solutions that can be fabricated in-house contributes to this trust. The focus groups thought that it was evident that the content was designed for their benefit and not a sales pitch (however, this impression may have been biased because the focus groups all knew the PI and the background to the site).

In light of these responses, the PI established the following decision-making rules for providing links to vendor websites:

- When a product is unique or a photo from the vendor's website is used, provide a link adjacent to the solution.
- When there are multiple vendors for equivalent products, place a list of links at the bottom of the page.
- When products are widely available, provide suggestions for a search term or simply state "available from most industrial suppliers" or equivalent.

Great care needs to continue to be made in maintaining a high level of trust in the content. In Phase III of the project, when advertisements and sponsorship come into play, the objectivity of the content will especially be important to emphasize.

Overall website content

The focus groups were all positive about the need for this site and that the prototype was developing in a good way:

- The amount of information on each page was satisfactory, that is, enough background to understand the solutions, but not so much detail to be a barrier.

- The information on the site is clearly needed by industry and unavailable elsewhere, especially practical, low cost solutions that are generally not known. The solutions can be found quickly and is in a format that is very helpful, i.e. an array of options from low cost to high end, provided in a context that is practical. Users were generally impressed by the depth and breadth of the solution data base.

- The interest level of the focus group participants was very high, which itself was a measure of the significance of the website. "This is very valuable information for us. Anything we can do to make the site more user-friendly will only benefit us."

- The list of solutions is comprehensive. No major gaps in information were noted.

- No equivalent sources of information were known.

- The information was down-to-earth and could be accessed by supervisors or safety committee members. By implication, small manufacturers without professional safety staff or engineering staff could access and apply the information.

Appendix A
Material Handling — Categories and subcategories

Pallet and container lifts
fixed height
spring-loaded
floor flush
overhead
portable
turntable
manual pump

Conveyors
standard belt and roller
flexible
multidirectional
inclined
overhead
auger/screw
air

Slides
standard steel
slippery plastic
skid bars
hinges
air tables
flush
unique

Conveyor gates
standard spring or cylinder
crossovers
counter-balanced
hinged
roll-out
ultra lightweight
belt conveyor gates

Carts
fixed height
adjustable
spring-loaded
drop-down side
powered
dollies and hand trucks
handles

Lifter-Transporter
lightweight
end effectors
pallet sized
front end support

Wheels
wheel diameter
axles
quality and material
fixed vs. swivel
tracks and runways
wheels for flexibility
temporary wheels

Air casters
material handling
equipment movement
common pitfalls
adaptations

Tuggers/pushers
tow motors
heavy walkie tuggers
lightweight maneuverable
tuggers
specialized pushers

Large containers
access doors
spring-loaded platforms
(false bottoms)
removable sides

Hand held totes
hand holds
size and weight
depth
hand clearance
formal guidelines
handling technique

Tilters
low cost
standard tilters
lift and tilt
cart version
potential hazard

Dumpers
low cost manual
low cost hoist systems
forklift mounted
self-dumping
standard powered
column dumper
manipulator arm
self-propelled

Pallets
plastic open-bottom
inverters
stackers
sliding technique

Hoists
alternatives to hoists
increasing loads
vacuum
electromagnets

Manipulator arms

Workstation Design — Categories and subcategories

Fixtures: bench top
backstop
pins
cradle
quick release
powered clamps
tiltable fixture
ball joints
rotating

Fixtures: free-standing
shop stands
positioner stands
pedestals
trunnions
work positioner
programmable positioner
upender fixture
welding jig

Height adjustment
risers
blocks/leg extensions
set screws/slide bolts
pedestals
pneumatic spring lifts
hand cranks
push button

Visual Access
heights, reaches, orientation
layout and location
guides and markers
mirrors
visibility

Lighting
overhead
task lighting
standard fluorescent
light boxes
head lights
special tasks
fiber-optic and LED

Magnification
basic magnifiers
light magnifiers
video systems
loupes

Parts handling
design to slide
minimize distances
parts stands
parts presenters
orient for use
parts holders

Storage
5S
casters
shelf heights
articulating arms
carousels
lateral sliding bins
aprons

Surface dimensions
minimize surface dimensions
eliminate the surface
temporary additional space
cutouts

Surface material
matte
low friction
high friction
special
thickness

Slanted surface
benchtop stands
slanted bench
slanted production line
slanted machine orientation

Standing platforms
basic
stackable
drop down/swing out
rack style
portable step platforms
hand crank
powered, large & small

Arm supports
ledges
articulating arm
slanted supports
designed into machine
bench edge cushioning
small benchtop cushions

Clearance
thin surfaces
raise heights
indents and recesses
extend controls

Sit-stand
standing height with tall stool
adjustable workstation

Seating
features of a good chair
lumbar support
slant vs. right angle
lean stands

Flooring
woodblock
wood decking
grating
anti-fatigue mats
rubber sidewalk

Footrests
sitting or Standing
box
step stool
rocking
adjustable height
chair ring
built-in

Appendix B
Usability Demographics

	Goal			Actual		
Total subjects	35			48		
Ethnic Category	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Latino	2	2	4	3	5	8
Non-Latino	15	16	31	19	21	40
Total	17	18	35	22	26	48
Racial Category						
Asian	1	1	2			
Black	1	2	3			
White	15	15	30			

Focus Group	Subjects
1	3
2	5
3	8
4	6
5	3
6	4
7	4
8	8
9	7
Total	**48**

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