Financial Considerations of a Proposed Lift Assist
At SGI, Chippewa Falls
Manufacturing Site

by

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ABSTRACT

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The American Psychological Association Manual Was Used for This Study

A new product is being built on the production floor of SGI at the Chippewa Falls manufacturing site. This product brings with it several new and unique manufacturing processes that may require new material handling equipment. The material handling device that SGI plans to purchase is a pneumatic lift assist device. This device would be considered a capital expenditure. This paper will determine if the pneumatic lift assist is the proper solution to for SGI to purchase by

preparing a cost benefit analysis. This analysis will determine whether or not the too being considered will pay for itself in a timely manner. The cost comparison will be the cost of the equipment to the cost of potential losses that may be incurred with any injuries that may result if the tooling is not in place within the time line of the return on the capital investment.

Conclusions will be drawn and a suggestion will be made to SGI, in regard to the purchase of the equipment by use of the information contained in this analysis. SGI will also be given a time line for the return on capital investment for the device.

Table of Contents:

Appendices

Chapter 1

Statement of the Problem

Introduction:

According to The US Department of Labor's *Workplace Injury and Illness Summary*, "A total of 5.9 million injuries and illnesses were reported in private industry workplaces during 1998." (DLR, 1999) While there was a decrease in the incidence rate of work related injuries and illnesses in private industry between 1994 and 1998 from 8.4 to 6.7 (BLS, 1999), there is still much work to be done with regard to protection of employees in American industry.

According to the United States General Accounting Office (GAO), these injuries cost an estimated 60 billion dollars in workers' compensation annually, to private sector American industry. (GAO, 1997) Of this 60 billion dollars, the GAO estimates that as much as one third of the dollars spent are due to musculoskeletal disorders (MSD). (GOA, 1997) The University of Florida, Florida Cooperative Extension Service (Circular 823, 1992) estimates that, "Back injuries alone cost American industry 10 to 14 million dollars in workers' compensation costs and about 100 million work days annually."

Silicon Graphics Incorporated (SGI) is a producer of high performance server and advanced graphics computers. SGI has manufacturing sites in Chippewa Falls, Wisconsin and Cortillod, Switzerland. SGI purchases sub-assemblies to computer systems and integrates these assemblies into computer systems at the Chippewa Falls and Cortillod sites. Starting July of 2000, SGI began production of a new class of computer system. Through the proto-type phase of the new systems, several areas of concern were made apparent. The new systems, while similar to others SGI produces, brought with them new production/assembly challenges. Some of the sub assemblies, “bricks,” weigh in excess of seventy pounds. These bricks will arrive at the factory on pallets in a multiple brick package. They will then be lifted from the pallets and be manipulated by production personnel and installed into standard computer industry nineteen-inch racks. The lowest height that a brick must be lifted from is eight inches from floor level. The highest level that a brick must be lifted for installation into a rack is fifty-four inches. The process steps associated with integration of the bricks into a computer system will consist of: raising the brick from the pallet, integration of components to the brick, integration of the brick into a nineteen-inch rack.

Of note to this process, the work force consists of both males and females. The approximate age range is from mid to late twenties through the mid to late fifties in years old.

The new computer build process that SGI began in July, 2000 may put employees at risk of MSD injuries. SGI must determine if the material handling equipment specified for the new build process will be feasible from a financial standpoint, compared to the risk of loss due to muskuloskeletal disorders that may be experienced by employees.

Purpose of the Study

The purpose of this study was to understand the risk associated with integration of a new computer system at SGI, Chippewa Falls, by assessing the integration task using the NIOSH Lifting Guide and to determine the cost effectiveness of engineering controls that may have eliminated the risk.

Goals of the Study

The goals of this study were to:

1. Identify risk factors of manual handling and associated costs of injuries that may have been incurred by SGI employees at the Chippewa Falls manufacturing site as a result of manual handling of bricks.
2. Determine the acceptability of manual material handling of bricks using the NIOSH Lifting Guide.
3. Determine the cost effectiveness of engineering controls specified to reduce the risk of manual material handling of bricks at the Chippewa Falls site.
4. Determine a cost benefit ratio for the engineering controls specified to reduce the risk of manual material handling of bricks at the Chippewa Falls site.

Background and Significance

SGI is committed to the health and well being of its employees. New computer products bring with them new build processes. With new processes come new challenges to protection of employees. These new processes need to be identified and defined with regard to the health and well being of employees. SGI is also a business. A business can not survive if sound financial practices are not followed. Part of sound business financial plans are cost benefit analyses, or financial justifications of capital expenditures. This analysis must be made with sound reasoning and not by off-the-cuff decisions. This study will help SGI make a sound financial decision in regard to the processes, that may put employees at risk of injury building new computer assemblies, that will begin in the July, 2000 time frame.

Definitions

Bricks – Sheet metal computer subassemblies that are integrated into a computer system. These subassemblies consist of a sheet metal shell that contains components of a computer system such as: memory, disk drives, power supplies, and input/output devices. (SGI, 1999)

Muskuloskeletal Disorders – Conditions that involve the nerves, tendons, muscles, and supporting structures of the body. (U.S. Department of Health and Human Services, 1997)

Summary

The new product line at SGI at the manufacturing site in Chippewa Falls, Wisconsin will present new challenges. Among these challenges will be the protection of employees from MSDs. These challenges must be met in a manner that both protects the employees and is cost effective for the company. A plan has been presented and has a cost associated to it. This cost must be weighed against the potential risk/cost of employee injury. This study will help SGI make a sound financial decision in regard to the processes, that may put employees at risk of injury building new computer assemblies.

Chapter 2

Review of Literature

Musculoskeletal Disorders/Back Pain and Cost:

"Musculoskeletal disorders (MSD) are among the most prevalent medical problems in the U.S., affecting 7% of the population." (Rosenstock, 1997) Rosenstock goes on to explain that 14% or medical visits and 19% of hospital stays are the result of MSDs.

In the 1994 report from the Bureau of Labor Statistics reported that, "… approximately 32%, or 705,800 cases, were the result of overexertion or repetitive motion." (Rosenstock, 1997) She reports that:

*There were 367,424 injuries due to overexertion in lifting. The majority (65%) affected the back. Another 93,325 injuries were due to overexertion in pushing or pulling objects (52% affected the back). In addition, there were 68,992 injuries due to overexertion in holding, carrying, or turning objects (58% affected the back). The median time away from work due to their injuries was six days for lifting, seven days for pushing/pulling, and six days for holding/carrying/turning.

*92,576 injuries or illnesses occurred as a result of repetitive motion, including typing or key entry, repetitive use of tools, and repetitive placing, grasping, or moving of objects other than tools. Fifty-five per cent of these affected the wrist, followed by 7% affecting the shoulder, and 6% affecting the back. The median time away from work was 18 days as a result of injuries or illnesses due to repetitive motion.

*The remaining 83,483 occurred in the other and unspecified overexertion events.

Jill Shelley and Michael Dennis report in *Muscle, Bone, and Back Injuries,* Oct., 1993 (a study prepared for Kansas State University) that back problems are, outside of headaches, the most common medical complaint and are second only to common colds as a cause for lost workdays. The figure they site as a cost is, "… $10 - $14 billion in workers compensation costs and about 100 million lost workdays annually."

An article published by the National Occupational Research Agenda (NORA) claims that 27% of all nonfatal occupational injuries and illnesses that involved days away form work in the United States were a result of back pain. The article claims also that the average claim to workers compensation is $8,300, which is more than twice the average cost of all compensable claims combined (an average of $4,075). All back pain combined cost American society an estimated $50 - $100 billion per year in 1990, approximately $11 billion dollars of which was charged to the workers compensation system. These figures are a result of an approximation that as many as 30% of American workers are employed in jobs that require them perform activities that may increase their risk of developing low back pain. (NORA, 1998).

Charles M. Jeffress, Assistant Secretary for Occupational Safety and Health US Department of Labor, in his testimony to the Subcommittee on Employment, Safety, and Training of the Senate Health, Education, Labor, and Pensions Committee, explained on 27 April, 2000, that muskuloskeletal disorders, "…are the most widespread occupational health hazard facing our Nation today." (OSHA, 2000). The figures he provides are, approximately two million workers are affected each year and that approximately 600,000 of those suffer a loss of work time from those injuries. The median number of lost workdays he cites is seven. He goes on to state that one of every three dollars spent for workers' compensation is spent as a result of insufficient protection from such injuries. The total cost he estimates is $15 to $20 billion per year and total costs that reach $45 to $54 billion.

Mr. Jeffress goes on to explain the human factor of these injuries by sighting examples of individuals that suffer from MSDs. One incident he cites is that of a professional person that works for the New York school district who herniated a disk in her back assisting a wheelchair-bound student. She, in the course of her duties, had to lift the student (assistance in the bathroom, for example). She had received no training in proper lifting techniques nor had she been given any form of personal protection equipment. He states that she may very well be permanently partially disabled as a result.

Mr. Jeffress went on to cite more examples of personal injuries. He intended to address and raise awareness of the potential risks facing the US workforce and explain the need for more government control in the workplace.

One of the more interesting concerns he raises is that, "… as many as 50% of workers do not report their MSDs" (Jeffress, 2000). He cites thirteen studies that contain information on "hundreds of thousands" of workers. He goes on to explain some of the reasoning as to why employees do not report, but the message is that no one really knows the total cost or risk associated with MSDs.

OSHA reports that certain factors contribute to the MSDs. Two factors discussed in this appendix are age and gender. As MSDs relate to age, OSHA reports that MSDs increase in people as they enter their working years. At the age of 35 most workers have encountered their first back pain/injury. From the ages of twenty-five to sixty-five the incidence of back injury is, for the most part, constant. Of note also, male workers between the ages of twenty and twenty-four and females between the ages of thirty and thirty-four experience the highest incidence of compensable back pain.

Advancing age and an increase of work years, according to the study, are more often than not, highly correlated. Age alone did not seem to impact the incidence of MSDs. A study by Mathiowetz et al. from 1985 in fact showed that hand pinch and grip scores remained more or less stable for the subjects studied. The subjects were of an age range from 29 to 59 years. Another study cited, conducted by Torell, Sanden, and Jarvholm in 1988, did not find a correlation between person's age and the prevalence of MSDs in a population of shipyard workers.

While there are studies that indicate a lack of correlation to increased age with an increase in the incidence of MSDs, it must be pointed out that an explanation may be found in what is called "survivor bias." This means that workers that experience pain on the job may, in fact, leave the job for something less likely to cause more or aggravate an existing painful condition. The remaining workers are those that are not adversely affected by the job. It is, because of this survivor bias, difficult to infer whether or not age has a strong influence on workers for a given age group with regard to MSDs. The true effect of survivor bias may vary well be that the risk to older workers is underestimated.

The OSHA Appendix 1 also sites studies that try to draw conclusions as to the effect of gender and the incidence of MSDs. This, too, is inconclusive because there are studies that indicate both higher rates of MSDs in women than men, and some that found no significant difference. One cause sited for a larger amount of women suffering from MSDs was that women are more likely to report pain at work than men are. Of note also is that fact that women are more likely to be employed in hand-intensive labors than are men, which may lead to more of certain types of MSDs.

A study described back pain as something that was, as reported by individual workers, pain in any region of the back that occurred for every day or more during a twelve-week interview period. This study showed that, in the twelve-month period, back pain due to the interviewees most recent job was at the rate of 2.5%, or 2.62 million workers in the United States (Behrens et al, 1994)

The study also points out that these statistics may be misleading in that the figures that were used may not represent a true picture of the rate of injury. It is noted that the statistics generated did not fall in line with the rates determined by the Bureau of Labor Statistics' rates. The Bureau of Labor Statistics rate was lower. It is felt that the most likely cause for the discrepancy is that only the most severe cases were reported to the Bureau. (Behrens et al, 1994)

Beherns also states that, “The cost of back injuries motivate people to report them…. the mean cost estimates in the 1980's for lower back pain claims ran from $5739 to $7004 per case.”

Another limitation to the study was that the act of a person “self reporting” of conditions related to work may be over or under reported. Conditions or incidents may go under-reported if the worker is being injured due to repeated or chronic injuring activities. They may be less likely to attribute the condition to work alone. Also, delayed onset of pain may not be attributed to an activity at work.

Over-reporting of conditions may occur when individuals are more aware of hazards. Training may lead to such awareness as well as a history of injuries attributable to specific tasks (Behrens et al, 1994).

Brad Berkowitz states in his article for the *ECS Risk Control Library*, that there are thousands of workers injured each year in the United States while moving or lifting objects. The costs of these injuries are reflected to industry in increased insurance premiums, disability payments, and lost productivity. Twenty-five percent of these injuries can be attributed to overexertion on the job. The cost to employees from these injuries is loss of income and sometimes loss of livelihood. For companies to remain competitive in the market place, the issues of these injuries must be addressed with proactive measures. (Berkowitz, 2000)

To address these issues, industry must make its stance by incorporating screening methods and the practical application of the NIOSH Lifting Equation. (Berkowitz, 2000)

Plant Engineering magazine states that in the past it was commonly felt that jobs requiring movement of an object weighing less than 50 pounds in repetition were acceptable. However, 30% of occupational injuries were caused by tasks that overexerted employees by forcing them to lift and or carry objects that weighed less than 50 pounds. A majority of the resulting injuries were to the lower backs of the employees. These can be the most expensive to companies in workers' compensation costs and lost time. Average direct costs of $4000-$7000 are to be expected, with the more severe injuries costing in excess of $50,000. (Paxton, 1997)

In a study of preventive approaches to back injuries, Stover H. Snook describes a study that was completed by the issuance of 219-questionnaires through Liberty Mutual Loss Prevention representatives.

The determinations made from the data collected were that 57% of low back injuries involved sudden sharp pain sensation during specific acts or movements. Thirty-one percent of low back injuries were the result of slight pain sensations during specific movements that increased (pain level) over a one-to-two day period. Another 12% of the injuries could not be attributed to any specific movement or task but were noticed, again, over a one-to-two day period with increased sensation of pain. Each of the reported acts was assigned a percentage of the total back injuries. The total percentage was over 100 because there were multiple movements associated with many of the injuries. Seventy percent of all the injuries were in some way associated with the tasks of lifting, lowering, pushing, pulling, and carrying. Lifting was attributed to nearly half of all injuries. Of all lifting tasks, 66% started below 31 inches and these 66% were associated with 78% of the total lifting injuries (Snook, 1978).

One of the preventive measures Snook discusses is job design. He points out that too often material handling tasks are evaluated by the weight of an item alone. This evaluation loses credibility for the fact that physical strength varies greatly among individuals. Instead, Snook suggests that physical acts be evaluated on the basis of two groups. One group, or category, of acts is manual handling tasks that 75% or more of the working population can perform without overexertion. The second category is that of tasks that less than 75% of the working population can perform without overexertion. He sites, for example, that 75% of the male working population can lift a common size box weighing 45 pounds from the floor and can exert an initial horizontal pushing force of 69 pounds without overexertion. The values sited for equivalent female workers are 33 and 52 pounds respectively (Snook, 1978).

The data reviewed in the study indicated that 23.6% of jobs evaluated involved manual tasks that less than 75% of the working population could perform without overexertion. The null hypothesis was that both groups (less than 75% and more than 75%) were equally susceptible to low back injuries. Of the 299 questionnaires reviewed, 145.9 injuries were expected in the 75% or more group and 45.1 injuries were expected in the less than 75% group. The actual numbers observed were 98 in the 75% or more group and 93 in the 75% or less group. Snook used the chi square statistic to test the null hypothesis and determined the value to be 66.60. The value was determined to be statistically significant at the .01 level of probability and the null hypothesis was therefore rejected (Snook, 1978)

Three conclusions were made as a result of Snook's study. The first conclusion was that selection, or fitting an employee to a task, is not valid. To support this conclusion, Snook states that as many injuries were experienced by employers that used medical histories, items such as medical exams and x-ray evaluations, as were experienced by employers that used no selection techniques. The second conclusion was that training of individuals in proper lifting techniques had no impact on the rate of injuries. Again, as many injuries were experienced by employers that performed training as those that did not. Snook supports this finding by citing a study in which it was stated that there had been no significant reduction in the prior 30 years when the straight back and bent knee lifting process had been performed. He also cites a Swedish study in which nurse aids were trained on correct lifting techniques. The training was reinforced every third month, but they experienced no reduction in the rate of injuries. Thirdly, Snook states that the only effective control for lower back pain and injury rates in the workplace is an ergonomic approach, or, designing the job to fit the workers.

<u>NIOSH Revised Lifting Equation: (unless otherwise stated, all information in this section has come from Waters, Putz-Anderson, and Garg, 1994)</u>

In 1985, the National Institute for Occupational Safety and Health (NIOSH) convened a committee of experts who reviewed the current literature on lifting, including the NIOSH WPG (1981). The literature review was summarized in a document called the Scientific Support Documentation for the Revised 1991 NIOSH Lifting Equation: Technical Contract Reports, May 8, 1991. The literature summary contains information on the physiological, biomechanical, psychophysical, and epidemiological aspects of manual lifting. Based on the results of the literature review, the committee recommended criteria for defining the lifting capacity of healthy workers. The committee used the criteria to formulate the revised lifting equation.

It must be stressed that the NIOSH lifting equation is only one tool in the effort to prevent work-related low back pain and disability. Also, lifting is only one of the causes of work-related low back pain and disability. Other causes, which are thought to cause or have been established as risk factors, include whole body vibration, static postures, prolonged sitting, and direct trauma. Psychosocial factors, appropriate medical treatment, and job demands also may be important in influencing the transition of acute low back pain to chronic disabling pain.

The Equation:

The recommended weight limit (RWL) is the product of the revised NIOSH lifting equation. The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time, such as an eight hour shift, without an increased risk of developing lifting-related lower back pain or injury. Healthy workers can be defined as workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.

The RWL is defined by the following equation:

RWL = LC x HM x VM x DM x AM x FM x CM (where)

Load Weight (L) =
Weight of the object to be lifted, in pounds or kilograms, including the container.

Horizontal Location (H) =
Distance of the hands away from the mid-point between the ankles, in inches or centimeters (measured at the origin and destination of lift).

Vertical Location (V) =

Distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift).

Vertical Travel Distance (D) =
Absolute value of the difference between the vertical heights at the destination and origin of the lift, measured in inches or centimeters.

Asymmetry Angle (A) =
Angular measure of how far the object is displaced from the front (mid-sagittal plane) of the worker's body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). The asymmetry angle is defined by the location of the load relative to the worker's mid-sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.

Lifting Frequency (F) =
Average number of lifts per minute over a 15-minute period.

The "M" designation in the formula refers to multipliers. These multipliers are obtained from tables that can be found in the Appendices A-G of this study. These multipliers can also be derived from the formulas given in the following equations:

1) Load Constant, (LC): Equal to 23 kilograms (metric) or 51 pounds (US customary).
2) Horizontal Multiplier, (HM): Equal to (25/H) metric and (10/H) US customary.
3) Vertical Multiplier, (VM): Equal to 1-(.003|V-75|) metric and 1-(.0075|V-30|) US customary.
4) Distance Multiplier, (DM): Equal to .82+(45./D) metric and .82+(1.8/D)
5) Asymmetric Multiplier, (AM): Equal to 1-(.0032A) metric and 1-(.0032A) US customary.

6) Frequency Multiplier (FM): See Appendix E.

7) Coupling Multiplier (CM): See Appendix G.

Once the RWL is calculated, it is compared to the actual load (L) of the object being lifted. If the actual weight of the load is less than that of the RWL for the object/task, the operation, or lift, is assumed to be safe. If the weight of the load is less than three times the RWL, the operation requires engineering changes or administrative changes such as worker rotation. If the actual load weight is more than three times the RWL, the operation is unacceptable and puts the employee at high risk of injury. These situations require engineering measures such as lift assist equipment or total task redesign. (Paxton, 1997)

Cost Effectiveness:

What is a cost effectiveness analysis? As described by Michael Biancardi, a cost effectiveness analysis is, "… a method to compare the cost of alternatives for achieving an agreed-upon goal." (Biancardi, 1978) For this study, the cost that will be identified, and determined to be effective or not, is the cost of equipment that will engineer the risk of back injury out of the computer integration process at SGI, Chippewa Falls Mfg. The cost "effectiveness" is the desired result of eliminating the risk, "the agreed-upon goal." Put another way, there was a cost that could be associated with risk control methods and the effect was to eliminate that risk.

A cost effectiveness study is difficult to apply when determining the effectiveness of risk control. One must determine what is and is not acceptable risk before one can determine the cost that is acceptable to eliminate it. The idea of using a cost effectiveness study must be approached with caution in that one may be compelled to look strictly at the economics side of the equation but will not define the details of what is and is not an acceptable risk. (Biancardi, 1978)

For the purpose of this study, David Randall was contacted. David Randall was, at the time of this study, the Production Manager for the existing and new products at the Chippewa Falls, SGI manufacturing site. When asked what is and is not acceptable risk, Mr. Randall stated that, “no risk is acceptable. There is no reason that risks can not be engineered out of the production floor.” He went on to state that there is no reason to spend more than is necessary to engineer out the risks, but that the company (SGI) is willing to spend whatever is needed to do so within reason.

So what is and is not safe? Again, to determine what is and is not safe is not a matter of a qualitative analysis. The analysis is simply a measure of what is and is not acceptable, done by analyzing historical data. Different people have differing ideas of what is and is not an acceptable risk, but without historical data, it is difficult at best to say what is and is not acceptable. Tasks can and are judged as safe or not safe, both prior to and after they are performed. Whether or not a task is safe is no more than a judgement of the acceptability of risks and can be described as a normative and political activity. To judge or measure risk is to measure the probability and probable severity of harm. This is done as an empirical and scientific activity. (Biancardi, 1978)

In the search for answers as to the cost effectiveness of engineering controls for ergonomic risk, opinions vary. The Occupational Safety and Health Administration (OSHA) feels strongly that ergonomic programs are indeed cost effective. The debate over the proposed OSHA ergonomics program is, at the time of this study, very alive. Diane Ritchey sites in her article *The Economics of Ergonomics,* that OSHA insists that ergonomic programs are cost effective and feasible. She goes on to say that OSHA sites scientific studies that produce evidence of MSDs related to the work environment. She also states that OSHA feels that the impact of, effectiveness of, ergonomic programs would prevent "32,000 to 95,000 injuries per year" and that the proposed regulations would cost US employers $3.5 billion in the first year and that the cost would decline in the years to follow. (Ritchey, 2000)

Ritchey also provides opposing views as to the economic effectiveness of ergonomics programs. She sites that opponents of the proposed OSHA ergonomics program state (this information is provided in this study to help explain the economics and cost effectiveness of ergonomics programs and is not intended to debate the OSHA proposed program) that there is not enough consensus among medical and scientific professionals as to what causes MSDs to simply say that ergonomics is cost effective. She also sites the opinion that many ergonomic programs overstate the benefits to such programs. (Ritchey, 2000)

Robert Grossman sites case studies in his article, *Make Ergonomics Go*, from HR Magazine, April 2000, that speak to the cost effectiveness of ergonomic programs.

One case study he cites is from KeySpan Energy. In his analysis he states that, "The direct cost of back injuries is only the tip of the iceberg," that one must also realize the costs of replacing people and providing alternative assignments for workers that return from lost time injuries, and that those costs can easily be up to four times the cost of the injury itself. (Grossman, 2000)

Part of the effectiveness of engineered ergonomic controls sited by Grossman is the increased productivity and quality of products. Mr. Grossman sites Larry Hettinger, director of human factors and ergonomics at Arthur D. Little in Cambridge, Massachusetts, as saying he is "baffled" that organizations are reluctant to incorporate ergonomics programs, given the cost effectiveness demonstrated by companies that embrace them. He states that of the more than 50 ergonomic audits that Arthur Little has recently conducted, 95 percent have demonstrated positive returns on investment. Again, not only in cost savings of injuries, but in increased productivity of the workers. (Grossman, 2000)

3M Ergonomics Form & Function Newsletter (no author sited), sites an ergonomics program that was implemented at the New Ulm, MN, 3M site. Parts of the program that were incorporated in an effort to reduce the risk of MSDs were the incorporation of a vacuum hoist to assist in lifting cartons from conveyor lines and the redesigning packaging. At the time the program was implemented the cost saving projected in injury prevention was $305,000 per year. Again, increased productivity was cited as another benefit.

One tool to assess the cost effectiveness of an ergonomic program is provided in Appendix H of this study. It is the cost effectiveness comparison tool that was provided for this study by Dr. Elbert Sorrell, Director, Risk Control Graduate Program, University of Wisconsin Stout, July 2000. It will be used in Chapter Four of this study to put numeric data into context for the reader.

A review of past back injuries at the Chippewa Falls, SGI site was not made for this study. This is not provided because the process being evaluated is new and does not reflect historical experience of the factory. Actual costs of injuries at the Chippewa Falls site are not provided because that information is considered proprietary and company confidential by SGI.

To restate, cost effectiveness is the study of particular costs as compared to what is considered a desired future outcome. These costs may or may not represent the value placed on the desired outcome or effect. One can make assumptions and educated guesses as to what may or may not occur in the future, and from that, make a determination as to what costs are acceptable during the present to achieve the desired future effect.

<u>Cost Benefit:</u>

What is a cost benefit analysis? There are many ways to calculate a cost benefit, but the definition is simply a ratio of monies expended and what was gained as a result. This result should be plugged into the ratio in the same units as the cost, in dollars. The equation is very simple; the monies spent and the monies returned are the complicated elements.

A cost benefit analysis essentially looks for, or defines, the return on investment. In order to fully understand this there must be an accurate assessment of both the costs and the savings associated with a program; for this study, the costs and savings associated with MSDs and the savings associated with their prevention.

Carolyn M. Sommerich, in her study titled, “Economic Analysis for Ergonomics Programs,” provides a comprehensive assessment to ergonomic program expenditures with comparison to benefits over a period of time. She defines a capital expenditure as, “Projects that require significant monies to be spent at the beginning, with the expectation of benefits (savings, income, or both) in the future are referred to as capital expenditures.” (Sommerich, 1999)

In order to perform an assessment a program record must be defined. The program record includes costs and savings. For this study, the costs and savings that will be addressed include: Turnover and Training/Replacement, Absenteeism, Productivity, Rework and Scrapped Product, Wages, Overhead and One Time Costs. This section is based on Sommerich’s study.

Turnover and Training/Replacement costs are the costs that are associated with the replacement of experienced workers. There are three subdivisions included in turnover and training/replacement costs. They are:

1. Acquisition costs which are defined as costs associated with the recruitment, selection, and hiring. These costs include, but are not limited to, items

such as advertising, travel, screening and administrative costs.

2. Development costs, which are defined as costs associated with training. Development costs include, but are not limited to, on-the-job training and overtime that adjusts for lost production.

In order to determine on-the-job training costs, Sommerich suggests the following calculation:

Clc = Wd x (1-eff) x Td

Where,

Clc = Lost production due to learning curve effects, $

Wd = Daily wage rate (including benefits), $/day

Eff = New employee performance relative to seasoned employees (0 – 1 range)

Td = Time, or learning period in days.

To determine costs associated with the payment of overtime wages that would compensate for lost production, Sommerich suggests the following equation:

Cot = Weh x Th

Where**,**

Cot = Cost of overtime in dollars

Weh = Hourly excess wage rate for overtime in dollars/hour

Th = Time (number of overtime hours) hours

Separation costs are defined as costs associated with the departure of employees. These costs include, but are not limited to, severance packages, reduced productivity, and the costs of open positions.

A severance package is simply one time payment to an exiting employee upon the termination of employment.

Reduction in productivity can be measured using the "Lost Production" calculation provided above.

The cost of an open position can be calculated with the following equation:

Clpo = Wd x Td

Where,

Clpo = Cost of lost production due to the open position measured in dollars

Wd = Daily wage rate ($/day)

Td = Time (number of days position remains open) in days

1. Absenteeism (associated with ergonomic hazards) costs are measured in workers' compensation costs and monies paid to ill or injured employees during their absence from work. These costs should be represented by or substituted with insurance fees. Line items include wages (including taxes and fringe benefits) and insurance charges and fees.
2. Medical expenses: These expenses include payments to providers and insurance charges or fees.
3. Replacement costs: These costs can be obtained using information above regarding turnover.

Productivity can be adversely affected by working conditions. Just as productivity can be effected by tools and equipment that require maintenance or that are inoperable, so too can employees that are not in good working condition. To calculate the cost in lowered productivity on the human scale, the following calculation is provided by Carolyn Sommerich:

Su = Wh x Delta-eff x Tru

Where:

Su = Savings, ($/production unit)

Wh = Hourly wage rate ($/hour)

Delta-eff = Improvement in production time (% time reduction from reference time)

Tru = Reference time/unit

With this, it is worth mention that temporary changes in productivity can and should be measured and figured into total cost. This can be measured in lost production time (see Lost Production equation above) and in overtime monies spent to overcome lost production time (see Overtime to Compensate for Lost Production above).

Rework and scrapped product must also be figured into the total cost of an injury. These parts are parts that may be effected by dropping or damage incurred when an injury takes place. In order for this calculation to be accurate, per piece costs and rates of "standard" product must be available. The rates include material and labor costs of the parts. The equation for rework, again supplied by Sommerich, is:

CRdl = Wh x Rpu x Tru

Where,

CRdl = Cost of direct labor for rework ($/production unit)

Wh = Hourly wage rate ($/hour)

Rpu = Rework rate (units to rework/units of production)

Tru = Time for rework (hours/unit)

Costs of scrapped units of production are the material costs minus the salvage value of the units. Along with overhead costs, line items included in the total cost are direct labor, overtime and direct material loss less salvage value.

Wage costs must also be figured in to total cost. Wage costs are monies paid for employee productive work hours. This cost does not include absences or vacation time. Additional monies included are taxes, benefits, personnel, supervisory and administrative costs.

Overhead costs include costs that may be factored in are costs such as utility costs, insurance fees, and OSHA fines.

One-time costs are those that most typically are incurred with capital expenditures. Line items included here are equipment, fixtures, installation, maintenance, engineering time and operator training.

Sommerich writes that in order to calculate costs and savings for a project or program, the critical information that goes into all these calculations may come from numerous sources. Some of these sources are the personnel department, industrial/process engineering, along with the medical and safety departments. All data collected must clearly documented.

To evaluate a small project ("small" not being defined by Sommerich), she suggests that a payback period analysis be used. To calculate the payback period analysis, she offers the following equation:

PB = C/S

Where,

PB = Payback period in months or years, corresponding to "S"

C = One time project cost in dollars

S = Periodic savings (or income) per month or year

Now that costs can be determined, a cost benefit analysis can be performed. It is worth mentioning, however, that with ergonomic programs and engineering solutions there are also some benefits that cannot be shown on paper in dollars. These are the intangible benefits that may occur as the result of spending.

David C. Alexander and Tomas J. Albin discuss intangible benefits to ergonomic programs in their study entitled, "Economic Justification of the Ergonomics Process". They say:

"While corporations many not totally agree with Shakespeare that, 'he who steals my purse steals trash,'" they are certainly in agreement with him regarding the loss of their good name. There is often a sense of shared purpose or *esprit de corps* among all employees of a company. Certainly no manager worthy of the responsibility would intentionally seek to injure or place their employees at risk. Consequently, it may be possible to justify some programs because they are "the right thing to do." On the flip side, if such programs are regarded as "nice" to do, then they may be limited and realize their full potential for mutual benefit to both employees and the company. (Alexander & Albin, 1999)

The study also illustrates cost justification methods that are strictly cost and benefit measured in dollars. The methods illustrated are benefit/cost ratio, payback period, and losses vs. goods sold.

Benefit to cost ratio = Value of benefits / Cost of changes

When numbers are plugged into the equation the total should be greater than zero. Zero would indicate that the expenditure is "break even." Anything greater than zero indicates a positive return on the investment. A total of "one" would indicate that the benefit is 1x the cost, "two" would indicate the benefit is 2x the cost and so on.

Payback period (in years) = Costs per year / Benefits per year

Payback period defines the amount of time taken to "payback" the original investment.

Volume of sales required to offset loss = Cost of losses / Profit margin

This example will determine the amount (volume) of goods that must be sold (in dollars) to offset the cost of an injury.

Summary:

This review of literature has provided information that allows SGI in Chippewa Falls to determine what musculoskeletal disorders are and the costs associated their occurrence. It has provided information regarding the NIOSH Revised Lifting Equation and it use. It has provided information regarding Cost Effectiveness and Cost Benefit Analysis. With this information, chapter four will perform a study to provide information for SGI to make an informed decision whether or not to proceed with the purchase of a lift assist for the Origin 3000 work center.

Chapter 3

Methodology

This chapter is provided to allow the reader to see a logical sequence of events followed to complete this study. This sequence of steps for this study was as follows:

A. Chapter 1, with support of literature, was written to:

1. State the problem that was identified at SGI, Chippewa Falls, WI.
2. Identify the Goals of the study.
3. Provide the background and significance of the problem.
4. Define key terms.
5. Give a summary of the problem.

B. Chapter 2 is designed to provide you, the reader, with information or a review of literature as it applies to:

1. Musculoskeletal disorders (back pain) and associated costs.
2. The NIOSH Lifting Equation
3. Associated tables of multipliers necessary to apply the NIOSH Lifting Equation. These tables are found in the appendices of the study.
4. Cost effectiveness of engineering controls.
5. Cost benefit ratios

C. Chapter 3 is designed to outline the sequence of the study.

D. Chapter 4 analyzes the job tasks of the production floor of SGI Chippewa Falls and utilizes the information from chapter 2 in order to:

1. Determine acceptability of lifting tasks according to the NIOSH Lifting Equation.

2. Determine the cost effectiveness of proposed engineering controls designed to aid employees at SGI for integration of bricks into computer systems.

3. Determine the cost benefit of proposed engineering controls designed to aid employees as SGI for integration of bricks into computer systems.

E. Chapter 5 provides conclusions and recommendations for SGI Chippewa Falls.

Chapter 4

The Study

Introduction:

The Origin 3000 work center at SGI Chippewa Falls was set up to accommodate the pilot builds of the new systems. What this means is, that prior to beginning full production, the work center was set up to run a small quantity of systems through production and allow all those concerned to prove the manufacturability of the systems. It was a proving time for engineering, process documentation, and on-the-job training of production personnel. One of the stepping stones of production is the integration of bricks into the computer racks. These bricks are slid into the racks on mounting rails. The racks themselves are seventy-four inches in height. The problem of manual manipulation/maneuvering bricks was readily apparent. The bricks themselves have no point of good contact for manual movement. There is no proper gripping point on the bricks. They are sheet metal components that have the following weights:

C-Brick = 65 pounds

I-Brick = 69 pounds

R-Brick = 18 pounds

P-Brick = 70 pounds

X-Brick = 69 pounds

These bricks are stationed on the floor on wooden pallets. They are stacked twelve bricks per pallet (two stacks of six) and separated by corrugated sheets. In order to assemble the Origin systems, these bricks must be moved from the pallets to work stations, where they are worked on internally, then to the racks to be slid into place. They can be placed anywhere, top to bottom, within the seventy-four-inch rack.

Process Engineering proposed the purchase of a vacuum lift assist. This system combined with lift trucks would maneuver bricks throughout the assembly process. The proposed solution was to take bricks from the pallets with the vacuum lift assist and position them on the lift trucks. The lift trucks could then place the bricks onto workstations for internal work, then pick them back up to be placed into the racks. While slightly cumbersome, with the use of the vacuum lift and the lift truck, there would be no reason for a worker to perform any manual lifts of the bricks.

Tooling cost of the proposed solution is:

Vacuum Lift Assist = $30,000

Lift Truck = $5,600 (x2) $11,200

Total Cost = $41,200

Engineering time will not be figured into the cost. Aside from time spent with suppliers (which is negligible) the suppliers were leveraged to provide the total solution. The engineering cost was to be figured into the selling price of the system. Were these costs justified?

Risk Factors and Costs:

As stated in the introduction, the risk factors of manual integration of bricks for the Origin 3000 system are:

1. The shape of the bricks. These bricks are sheet metal boxes with no good grip point for manual handling. There are sharp edges and sometimes oil films on the metal.
2. The weight of the bricks. There is one brick that could be considered "light". The R-Brick weighs eighteen pounds. When asked, production personnel did not feel any type of lift assist would be of use for R-Bricks. They stated they would not use an assist for R-Bricks but could not physically handle the other types of bricks. The others, C, I, P, and X, average just over sixty-eight pounds.
3. The location of the bricks. The size of the bricks and the storage pallets they sit on require that they be stationed at a distance from the point of use. Limited floor space also requires that the pallets be placed at a distance.

All of these bricks must be worked on internally prior to being integrated into the system as a whole. This would entail movement of a brick from its storage pallet to a workbench and from there into an empty computer rack. Employees would be required to lift a brick from the pallet from a height ranging between four and thirty-eight inches. This range comes from the bricks being stacked six units deep on the storage pallet. The pallets were stored on the floor and were not stacked.

The bricks were then to be transferred to the workbench. The distance to travel from the storage pallet to the workbench ranged from twelve to twenty-eight feet. A cart could have been used to travel from the storage pallets to the workbenches, but then would require extra lifts to transfer the bricks from the cart to the bench then back to the cart from the bench. The distances, weights, and heights were taken directly from the production floor of SGI.

The racks that the bricks go into, after internal work, are on wheels. These could be moved to the workbench to make the transfer from bench to rack, thereby negating any travel distance. However, the bricks could be placed anywhere between eight and fifty-four inches high, depending on where in the rack the brick was required. The bricks were to be placed throughout depending on the configuration of the system. The systems were designed to be very flexible. This means that the employee may either have to bend down with the brick to place it or reach above their head to place it.

The movement of the bricks from the pallets to the point of use and the manipulation required to mount the bricks into the racks were unacceptable risks.

Reviewing the literature, it is assumed that there were costs (risks) to be associated with not installing a lift assist. Given the age and mix of both male and female employees, it was assumed there would be injuries. Exactly how many injuries is difficult to determine. For the purpose of this study, we assumed two injuries per year. What can be determined is the fact that if there were only one, the cost would have been in the $4,000-$50,000 range.

NIOSH RWL:

The RWL and Lifting Index for the bricks can be calculated from the equations and definitions listed in Chapter 2 of this study. A worksheet to perform this calculation is also provided as Appendix H. The calculation of the RWL both at source and destination shows that the RWL is four times greater than the actual load at the origin and slightly more than three times greater at the destination. Therefore, it can be stated that the operation is unacceptable without the aid of engineering controls. Appendix I of this study contains the values used to make this determination. For the calculation, a value of 68.25 pounds was used (average of the brick weight) and the best case scenario for vertical and horizontal values. These vertical and horizontal values were derived from measurements on the production floor. These values were for loading the bricks on to the workbenches only. Again, this was best case. The operation to place the bricks into the racks was determined to be a greater risk because of the low and high vertical movement of bricks. Appendix I can be used to make further determinations for integrating the bricks into a system rack.

Cost Effectiveness:

As was stated in Chapter 2, to determine cost effectiveness one must determine what is an acceptable risk. SGI management has stated that no risk is acceptable with regard to employee injury or illness. That being said, it can be stated that some type of risk control is necessary on the Origin 3000 production floor.

Therefore, the question is, is the proposed cost control effective? Using Appendix I, we can make that determination. To use the appendix we will use the following figures:

1. Average cost of MSD = $10,000
2. Life expectancy of the control (write off period) = 3 years
3. Number of injuries to be prevented per year = 2
4. Cost of controls = $41,200
5. Companies desired rate of return on investment = 6%
6. Average inflation rate over the write off period = 3%

The desired return on investment is taken from the bond rate at the time of the study. This is a conservative investment return. The inflation rate was determined from the national inflation rate at the time of the study.

Using these figures, it was determined that the total present value (at the time of the study) of injury payments for three years following would be $58,363. That value is derived for only three years and is presented for the purpose of the write off period which is also three years. A safe assumption was made that the lift assist would be used for a period of six years. The value of the savings over a six-year period was determined to be $111,932. The cost of the proposed control was $41,200. Using those calculations, it was determined that the payback period for the control was two years and two months.

Cost Benefit:

While similar to the cost effectiveness ratio, the cost benefit ratio will take into account several other charges that were not figured into the cost effectiveness. These other charges are outlined in Chapter 2 along with the formulas to derive them. Of note, because of lacking information (considered confidential by SGI), the daily wage rate was estimated at $112. Also, not appearing in the figures, are severance package costs, assorted administrative costs and overtime costs. Overtime costs were not figured in because SGI does not typically use overtime to make up for an injured employee. SGI cross-trains employees and would typically shift employees from another work area to cover for a missing employee. Two weeks of workers' compensation was also used at the rate of 66 2/3% of the $112 weekly wage rate. This is assuming an employee would miss work for two weeks due to an injury. The costs that were figured in were cost of lost production, cost of lost production due to an open position, and medical cost. The sum of these costs was $23,886. This is the cost that can be associated with one injury. If we assume two injuries per year as in the cost-effectiveness section, the cost doubles to $47,772.

The cost benefit ratio then becomes the value of benefits divided by the cost of the lift, which translates to $47,772 / $41,200 equaling 1.16. As was stated in Chapter 2, anything exceeding one designates a positive return on investment. It must be noted also that only the first 2 years are figured into this example.

Also of note, the volume of sales required to offset the first-year loss should also be considered. The formula for the volume of sales in this example would be the cost of the loss, $47,772, divided by the profit margin. At the time of this study, SGI's profit margin was 35%. This means that SGI would have had to sell $136,490 dollars worth of product to make up for the $47,772 dollars in losses. Again, extra work time of employees, administrative costs, added scrap costs and assorted overhead costs due to that extra production should be considered.

Chapter 5

Conclusions and Recommendations

Summary:

The Chippewa Falls, SGI Manufacturing Facility began builds of a new product in 2000. This product was the Origin 3000 high-end computer system. With this new product came new risks and challenges. Part of this challenge was the material handling required to move “bricks” or component parts of the systems. In order to reduce this risk, Process Engineering at SGI proposed a lift assist system combined with lift trucks. The purpose of this system was to eliminate manual movement of the bricks. The bricks had an average weight of 68.25 pounds.

The question, or purpose of this study was to determine if this manual movement of bricks was an acceptable risk, to determine if the proposed lift assist was cost effective, and if it provided a good cost to benefit ratio. Basically, would the lift assist be a good investment for SGI?

Procedures:

A review of literature was conducted to determine what costs and frequencies could be associated with muskuloskeletal disorders that may have occurred without engineering controls (a lift assist) put into place. These frequencies and costs were plugged into worksheets that are provided in the appendices of this study. To obtain figures to plug into these equations and worksheets, measurements were taken on the production floor of SGI, and equipment costs were obtained from SGI's Industrial and Process Engineering departments.

Findings:

Given the distances of required movements of bricks, the weight of the bricks, and the size and shape of the bricks, not only was the risk too great given the ages and sexes of the production employees, the bricks did not fall within the recommended guidelines set up by NIOSH.

It was proven that the lift assist technology was a cost effective control and that the lift assist also had a good cost to benefit ratio.

Conclusions:

It can be concluded that if the lift assist were to work as it was being designed/intended to work, and the employees would use it, it was a viable control. If it indeed removed the necessity of manual handling of bricks, the cost was in line and would have been a cost effective solution. The lift also would provide a positive cost to benefit ratio.

Recommendations:

Relating to this study, the recommendation was to purchase the lift assist technology combined with lift trucks. A "do nothing" approach would almost certainly have caused unnecessary risk and expense.

Recommendations include:

1. Proper maintenance of the equipment to prevent it from becoming a risk in and of its own. The reasoning behind this recommendation is that the lift is a tool. Unless properly maintained, this tool has the potential for injury to the employees.
2. Maintain history of any injuries that were to be prevented with the assist and understand why the assist did not perform properly. This is a check and balance to make certain the lift is performing as expected. If it does not, reevaluation of the tool must be made.
3. Training of employees for proper use of the assist. The recommendation is made to be certain that the employees know the proper operation and function of the tool in order to prevent damage to equipment or injury to the employees.
4. Administrative briefings to employees as to the importance of using the lift. This includes the reasoning behind its purchase and support of perhaps a slower work pace than if an employee did not use the lift. Employees must know the necessity of using the lift. They must also be aware that they will not be penalized for potentially lowered production rates.
5. The engineering departments concerned should be kept abreast of improvements to lift assist technology and its proper use and care. There may be new technology developed that would be more suited to this application.

References

Alexander D.C., Albin T.J. (1999). "Economic Justification of the Ergonomic Process." In Karwowski W. & Marras W.S. (Eds.), The Occupational Ergonomics Handbook (pp. 1495-1505), Washington, DC:CRC Press.

Becker, W.J. (1991). "Controlling Workers' Compensation Costs." Florida Cooperative Extension Service, University of Florida, Fact Sheet AE-81.

Becker W. J. (1992). "Proper Lifting, Pushing and Pulling to Prevent Strains, Sprains and Lower Back Pain." Florida Cooperative Extension Service, University of Florida, Circular 823 (Originally published in July 1989, last reviewed 1992).

Behrens V., Seligman P., Cameron L., Mathias T., Fine L. (1984)."The Prevalence of Back Pain, Hand Discomfort, and Dermatitis in the US Working Population." American Journal of Public Health, 84(11), 1780-1784.

Berkowitz, B. "Proper Lifting Prevents Injuries and Controls Costs." ECS Risk Control Library. Retrieved July 16, 2000 from http://www.ecsinc.com/riskctrl/hot/lift.htm.

Biancardi, M. (1978)."The cost/benefit factor in safety decisions." Professional Safety, 17-22.

Cunningham L.S., Kelsey J. L. (1984). "Epidemiology of Musculoskeletal Impairments and Associated Disability." American Journal of Public Health 74(6), 574-579.

Dennis M., Shelly J. (1993). "Muscle, Bone and Back Injuries." From "Health Concerns in Agriculture." Extension Agricultural Engineering, Kansas State University, Manhattan KS.

"Education and Counseling to Prevent Low Back Pain." (2000). United States Department of Health and Human Services. Retrieved July 10, 2000, from http://my.webmd.com/content/dmk/dmk_article_54333.

"Form and Function Newsletter." (2000). 3M Commercial Office Supply Division. Retrieved July 28, 2000 from http://www.3m.com/cws/issue1.html#Formula_for_Effective.

Fox, M. (1999). "Pain in the Back." Reuters News Service. Retrieved July 10, 2000, from http://www.abcnews.go.com/sections/living/DailyNews/backpain990630.html.

Grossman, R.J. (2000). "Make Ergonomics Go." HR Magazine. 45(4). Retrieved July 28, 2000 from http://www.shrm.org/hrmagazine/articles/0400cov.html.
Health, Education, and Human Services Division. (1997). "Private Sector Ergonomics Programs." (GAO/HEHS Publication No. 97-163). Washington, DC: U.S. General Accounting Office.

Jeffress, C. (2000, April). Congressional testimony on ergonomics. Speech presented to the Occupational Safety and Health Administration, US Department of Labor. Subcommittee on Employment, Safety, and Training of the Senate Health, Education, Labor and Pensions Committee. {On line}.

Jeffress, C. (1999). Congresstional testimony on work-related musculoskeletal disorders. Speech presented to the Occupational Safety and Health Administration, US Department of Labor. National Coalition on Ergonomics. {On line}.

Liles, D.H. (1985)."Using NIOSH Lifting Guide Decreases Risks of Back Injuries." Occupational Health and Safety , 57-60.

Miller D.P. (1999). "Corporate Cost Avoidance Using Sound Ergonomics Technology and Quality-Based Customer Services." In Karwowski W. & Marras W.S. (Eds.), The Occupational Ergonomics Handbook (pp. 1461-1474), Washington, DC:CRC Press.

National Institute for Occupational Safety and Health. (1997)."Work-Related Musculoskeletal Disorders." (NIOSH Document #7050005).

"Low Back Disorders." (1998). National Occupational Research Agenda, National Institute for Occupational Safety and Health.

Paxton, J. (1997)."Decreasing Employees' Backaches and Management's Headaches." Plant Engineering Magazine. Retrieved July 16, 2000, from http://www.manufacturing.net/magazine/planteng/7000/articles/97/124550.htm.

Ritchey, D. (2000)."The Economics of Ergonomics." Appliance Magazine. Retreived July 28, 2000 from http://www.appliancemagazine.com/mm/aline/html/02-00.html.

Rosenstock, L.(1997). Written Testimony Submitted to the National Institute for Occupational Safety and Health, Subcommittee on Workforce Protection.

Snook S. H., Campanelli R. A., Hart J.W. (1978)."Preventive Approaches to Low Back Injury." Journal of Occupational Medicine, 20(7), 478-481.

Sommerich C.M. (1999). "Economic Analysis for Ergonomics Programs." In Karwowski W. & Marras W.S. (Eds.), The Occupational Ergonomics Handbook (pp. 1475-1494), Washington, DC:CRC Press.

Waters T.R., Putz-Anderson V., and Garg A. (1994) "Applications Manual for the Revised NIOSH Lifting Equation." Retrived July 10, 2000 from http://www.aepo-xdv-www.epo.cdc.gov/wonder/prevguid/p0000427/p0000427.asp.

Appendix A

Horizontal Multiplier

H	HM	H	HM
Inches		**Centimeters**	
< = 10	1.00	< = 25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45
> 25	0	58	.43
		60	.42
		63	.40
		> 63	0

Appendix B

Vertical Multiplier

V	VM	V	VM
Inches		**Centimeters**	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
> 70	0	150	.78
		160	.75
		170	.72
		175	.70
		> 175	.00

Appendix C

Distance Multiplier

D	DM	D	DM
Inches		Centimeters	
< = 10	1.00	< = 25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	> 175	0
> 70	0		

Appendix D

Asymmetric Multiplier

A	AM
Degrees	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
> 135	0

Appendix E

Frequency Multiplier Table

Work Duration						
Frequency (F) Lifts/min.	**< = 1 Hour**		**> 1Hour**	**< = 2 Hours**	**> 2 Hours**	**< = 8 Hours**
	V < 30 +	**V > =30**	**V <30**	**V > = 30**	**V < 30**	**V > = 30**
< = .2	1.00	1.00	.95	.95	.85	.85
.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.35
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
> 15	.00	.00	.00	.00	.00	.00

\+ Values of V are in inches. For lifting less frequently than once per 5 minutes, set F = .02 lifts/minute

Appendix F
Hand to Coupling Classification

Good	Fair	Poor
1. For containers of optimal design such as some boxes crates, etc., a "Good" hand-to object coupling would be defined as handles or hand- hold cut-outs of optimal design.	1. For containers of optimal design, a "fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design.	1. For containers of less than optimal design or loose parts or irregular parts that are bulky, hard to handle, or have sharp edges.
2. For loose parts or irregular objects, that are usually containerized, such as castings, stock, and supply material, a "good" hand-to object coupling would be defined as comfortable grip in which the hand can be wrapped around the object.	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a fair hand to object coupling is defined as a grip in which the hand can be flexed about ninty degrees.	2. Lifting non rigid bags.

Notes:
1. An optimal handle design has 0.75-1.5 inches (1.9 to 3.8cm) diameter, >= 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has the following approximate characteristics: >= 1.5 inch (3.8 cm) height, 4.5 (11.5 cm) length, semi-oval shape, >= 2 inches (5 cm) clearance, smooth non- slip surface, and >= 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard).

3. An optimal container design has <= 16 inches (40 cm) frontal length, <= 12 inches (30 cm) height, and a smooth non-slip surface.

4. A worker should be capable oof clamping the fingers nearly 90 degrees under the container, such as required when lifting a cardboard box from the floor.

5. A container is considered less than optimal if it has a frontal length > 16 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymetric center of mass, unstable contents, or requires the use of gloves. A loose object is considered bulky if the load cannot easily be balanced between the hand-grasps.

6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

Appendix G

Coupling Multiplier

Coupling Type	**Coupling Multiplier**	
	V<30 Inches (75 cm.)	**V≥30 Inches (75 cm.)**
Good	1.00	1.00
Fair	.95	1.00
Poor	.90	.90

Appendix H
Job Analysis Worksheet

JOB ANALYSIS WORKSHEET

DEPARTMENT ____________________
JOB TITLE ____________________
ANALYST'S NAME ____________________
DATE ____________________

JOB DESCRIPTION
____
____
____

STEP 1. Measure and record task variables

Object Weight (lbs)	Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate	Duration	Container Coupling	
	Origin		Dest.			Origin	Destination	lifts/min	(HRS)	Origin	Destination
L	H	V	H	V	D	A	A	F		C	C

STEP 2. Determine the multipliers and compute the RWL's

$$RWL = LC \cdot HM \cdot VM \cdot DM \cdot AM \cdot FM \cdot CM$$

ORIGIN RWL = $\boxed{51} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} = \boxed{\text{Lbs}}$

DESTINATION RWL = $\boxed{51} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} \cdot \boxed{} = \boxed{\text{Lbs}}$

Determine multipliers from Tables 4-9

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = $\dfrac{\text{OBJECT WEIGHT (L)}}{\text{RWL}}$ = ______ = $\boxed{}$

DESTINATION LIFTING INDEX = $\dfrac{\text{OBJECT WEIGHT (L)}}{\text{RWL}}$ = ______ = $\boxed{}$

Appendix H, complete

JOB ANALYSIS WORKSHEET

DEPARTMENT: Production
JOB TITLE: Assembly Tech.
ANALYST'S NAME: Paul Eckel
DATE: N/A

JOB DESCRIPTION: Origin 3000 Production

STEP 1. Measure and record task variables

Object Weight (lbs)	Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Container Coupling	
	Origin		Dest.			Origin	Destination			Origin	Destination
L	H	V	H	V	D	A	A	F		C	C
68.25	14	4	14	32	28	45°	45°	<.2	8	Poor	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC · HM · VM · DM · AM · FM · CM

ORIGIN: RWL = $\boxed{51} \cdot \boxed{.71} \cdot \boxed{.80} \cdot \boxed{.88} \cdot \boxed{.86} \cdot \boxed{.85} \cdot \boxed{.9}$ = $\boxed{16.77 \text{ Lbs}}$

DESTINATION: RWL = $\boxed{51} \cdot \boxed{.75} \cdot \boxed{.98} \cdot \boxed{.88} \cdot \boxed{.86} \cdot \boxed{.85} \cdot \boxed{.9}$ = $\boxed{21.7 \text{ Lbs}}$

Determine multipliers from Tables 4-9

STEP 3. Compute the LIFTING INDEX

ORIGIN: LIFTING INDEX = $\frac{\text{OBJECT WEIGHT (L)}}{\text{RWL}} = \frac{68.25}{16.77} = \boxed{4.07}$

DESTINATION: LIFTING INDEX = $\frac{\text{OBJECT WEIGHT (L)}}{\text{RWL}} = \frac{68.25}{21.7} = \boxed{3.15}$

Appendix I

Cost Effectiveness Comparison

	1	2	3	4	5	6	7
			(1 X 2)		(3 X 4)		(5/6)
Year	**Potential Average Payment For One Injury**	**Goal – Number of Injuries Being Eliminated**	**Total Cost Savings In Current Dollars**	**Average Inflation Factor (1+infl. Rate) n-1**	**Actual Savings In Future Dollars**	**Discount Factor (1+Minimum Rate of Return on Investment) n-1**	**Present Value of Future Savings**
1st			$	(1.) 0=	$	(1.) 0=	$
2ond				(1.) 1=		(1.) 1=	
3erd				(1.) 2=		(1.) 2=	
4th				(1.) 3=		(1.) 3=	
5th				(1.) 4=		(1.) 4=	
6th				(1.) 5=		(1.) 5=	
7th				(1.) 6=		(1.) 6=	
8th				(1.) 7=		(1.) 7=	
9th				(1.) 8=		(1.) 8=	
10th				(1.) 9=		(1.) 9=	
11th				(1.) 10=		(1.) 10=	
12th				(1.) 11=		(1.) 11=	
13th				(1.) 12=		(1.) 12=	
14th				(1.) 13=		(1.) 13=	
15th				(1.) 14=		(1.) 14=	

8. (Sum Col. #7) Total Present Value of Injury Payments $ ____________
9. (Subtract) Cost of Controls - ____________
10. Present Value of Savings for Program $ ____________

Required Data

Average Cost of __________ Injury = $ ____________ (1)
Life Expectancy of Control (Write off Period in Years) = ____________
Goal: # of ________ Injuries to be prevented/year = ____________ (3)
Cost of Controls = $ ____________ (9)
Company's Opportunity Cost of Capital
Minimum Desired Rate of Return on Investment = ____________ (6)
Average Inflation Rate Over Write-off Period = $ ____________ (4)

Payback Period ____________ (Determine From Column (7).
The payback period is the time period needed for total savings realized to equal the original investment.

Appendix I, Complete

Appendix I
Cost Effectiveness Comparison

	1	2	3	4	5	6	7
			(1 X 2)		(3 X 4)		(5/6)
Year	**Potential Average Payment For One Injury**	**Goal – Number of Injuries Being Eliminated**	**Total Cost Savings In Current Dollars**	**Average Inflation Factor (1+infl. Rate) n-1**	**Actual Savings In Future Dollars**	**Discount Factor (1+Minimum Rate of Return on Investment) n-1**	**Present Value of Future Savings**
1st	$10,000	2	$ 20,000	(1.03) 0= 1.0	$ 20,000	(1.06) 0= 1	$ 20,000
2ond				(1.) 1= 1.03	20,600	(1.) 1= 1.06	19,434
3erd				(1.) 2= 1.06	21,200	(1.) 2= 1.12	18,929
4th				(1.) 3= 1.09	21,800	(1.) 3= 1.19	18,319
5th				(1.) 4= 1.13	22,600	(1.) 4= 1.26	17,937
6th				(1.) 5= 1.16	23,200	(1.) 5= 1.34	17,313
7th				(1.) 6= 1.19	23,800	(1.) 6= 1.42	16,761
8th				(1.) 7= 1.23	24,600	(1.) 7= 1.50	16,400
9th				(1.) 8= 1.27	25,400	(1.) 8= 1.59	15,975
10th				(1.) 9= 1.30	26,000	(1.) 9= 1.69	15,385
11th				(1.) 10= 1.34	26,800	(1.) 10= 1.79	14,972
12th				(1.) 11= 1.38	27,600	(1.) 11= 1.89	14,526
13th				(1.) 12= 1.43	28,600	(1.) 12= 2.01	14,229
14th				(1.) 13= 1.47	29,400	(1.) 13= 2.13	13,803
15th				(1.) 14= 1.51	30,200	(1.) 14= 2.26	13,363

8. (Sum Col. #7) Total Present Value of Injury Payments $ 247,619
9. (Subtract) Cost of Controls - 41,200
10. Present Value of Savings for Program $ 206,419

Required Data
Average Cost of __________ Injury = $ 10,000 (1)
Life Expectancy of Control (Write off Period in Years) = 3
Goal: # of ________ Injuries to be prevented/year = 2 (3)
Cost of Controls = $ 41,200 (9)
Company's Opportunity Cost of Capital
Minimum Desired Rate of Return on Investment = 6% (6)
Average Inflation Rate Over Write-off Period = $ 3% (4)

Payback Period 2 yrs. 2 mo. (Determine From Column (7).
The payback period is the time period needed for total savings realized to equal the original investment.