Cost-Benefit Analysis of Ergonomics Programs

AUTHOR
Maurice S. Oxenburgh

77 Ryan St., Lilyfield NSW 2040, Australia

A cost-benefit analysis method for calculating the cost of employment is described. The purpose of the analysis is to portray, in financ'al terms, the benefits to health, productivity, and quality brought about by improved working conditions. The analysis can be used to measure the financial benefits after the completion of changes to working conditions, or it can be used to show the potential value of proposed expenditure (improvements to working conditions) and thus compete for resources on an equal footing with other enterprise proposals. The cost-benefit analysis may also be used as a sensitivity analysis to detect areas of high labor cost (e.g., high injury absences) and/or productivity losses (e.g., low quality of service or product) and thus to direct workplace improvements toward these areas, if appropriate.

Keywords: activity based costing, cost-benefit analysis, ergonomics programs, labor costs, management, productivity

Estimating the anticipated costs of a proposed factory or process is a normal function of technical management. Part of the evaluation process is to anticipate the expected performance and derive from the expected costs and expected performance a cost-benefit ratio. In a similar fashion, evaluating a proposal before embarking on it can be used in personnel-related ventures, e.g., workplace safety.

When a cost-benefit analysis is performed on personnel-related ventures, there are frequently ethical constraints; for example, should a price be put on a life or a broken back? In practical terms, management has to do that all the time, albeit frequently without acknowledging or advertising the fact. When too low a price is put on workplace safety, governments may regulate to increase the apparent value of human life and health. Many of these ethical issues and some of the practical difficulties have been discussed, for example, by Bequele.[1]

Increasingly, governments judge the benefits to be gained from regulations with their costs. In Australian workplace safety legislation it is now customary to estimate the costs for implementation of proposed regulations before a regulation is promulgated. Unfortunately, the methods to measure such effects are not yet substantiated and often the methods used are not published. Nevertheless, the concept is in place, notwithstanding the ethical issues and practical difficulties.

There have been several attempts to use the cost-benefit concept to balance the conflicting views between the need for regulations and the costs to implement them. In the late 1980s the costs and benefits of the introduction of a National Safe Manual Handling Code of Practice in Australia was investigated prior to its introduction by Oxenburgh and Guldberg.[2] One of the findings of that investigation was that industry had been reducing its reliance on manual handling, not necessarily to reduce workplace injuries but to increase workplace efficiency by decreasing its reliance on manual handling. The estimated additional costs to industry due to the introduction of the Manual Handling Code was relatively small.

Taking a large and nationwide slice of industry, as in the Oxenburgh and Guldberg study, has certain drawbacks as many assumptions have to be made and, by the very nature of the study, cannot be substantiated. One assumption relates to the types of injuries: all back injuries are grouped singularly as "back injuries" even though the multitude of injuries varies in locus, degree, and tissues affected. Another assumption relates to the national statistics for the causes of back injuries; it is known that these statistics are unreliable but, in the absence of anything better, are used. In addition, expanding a sample of workplaces to the nation level, although using standard statistical procedures, gives national figures that cannot be verified.

This inaccuracy of assessment of benefits and costs is not the case in all industries. For example, in lead or vinyl chloride use the methods for measuring exposure are relatively simple and may

Copyright 1997, American Industrial Hygiene Association

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

be done reasonably accurately by the industries concerned. The diseases are known and specific to that agent. In these and similar industries it can be expected that the costs and benefits of regulations may be calculated with reasonable accuracy both at the national scale and at the individual workplace.

It is the workplace safety factors known as "ergonomics factors" in which the costs and benefits of changes cannot be so easily measured. It is almost always the case that these ergonomics factors are multifactorial. These ergonomics factors, if not controlled, may lead to physical injuries, such as musculoskeletal injuries to the back and upper limbs, and perceptual errors that lead to faulty actions (as occurred in the Three Mile Island nuclear power plant).

Because these ergonomics factors cannot be easily measured or the potential outcomes accurately estimated it does not mean that they or their economic consequences should be ignored. The economic cost of these factors far outweighs the costs to the national economy of, for example, lead and coal dust diseases. In the Oxenburgh and Guldberg study the estimated costs for back injuries due to manual handling in the selected industries was approximately $7,000 (Australian) per back injury. In the United States the cost has been estimated by Snook[3] at about $5,200 (U.S.) per back disorder. These two costs, after allowing for exchange rates, are quite similar. The costs, after expansion to the national level, are quite astronomical.

There are usually very good statistics on workers' compensation (insurance) costs but only poor information on the indirect costs (absence, supervision, production losses, etc.) to the workplace where any particular injury occurs. Andreoni[4] has collected the indirect costs for workplace injuries over a range of industries in various countries and has indicated that these costs vary between 0.5 and 20 times the wage or salary costs. The Oxenburgh and Guldberg study used a factor of 0.75 of the direct costs to be added as the indirect costs, although this did not include losses of productivity and profit to the employer.

Clearly, in a cost-benefit analysis for a particular workplace it is not valid to use derived indirect cost factors (for example, from Andreoni). Fewer assumptions, with no expansion factors, are required when looking at individual workplaces or in a relatively small or restricted industry. To return to the introductory paragraph, each new factory or process requires a cost-benefit analysis, and personnel-related ventures (safety) are no different in concept. It only remains to develop a model for such an analysis.

In the late 1980s Liukkonen[5] developed such a system in which she demonstrated the individual costs that related to worker performance and productivity. These costs included productive time, productivity losses due to absence, costs for training and employee turnover, as well as the costs of wages/salary, taxes and insurance.

A similar approach was taken by Parenmark et al.[6] when comparing the labor turnover, absenteeism, and quality of product when comparing a new process system with an older system. In a detailed study of four cases Helander and Burri[7] illustrated the effectiveness of ergonomics improvements programs at IBM by the use of cost-benefit analysis.

Much of the work referred to above was either not generally available to English-speaking people (Liukkonen published mainly in Swedish and Finnish) or was not systematically presented, being more concerned with illustrating the ergonomics rather than the economics, as in the examples of Parenmark and Helander.

Dahlén[8,9] defined the workplace in terms of Activity Based Costing. This is an approach in which the costs are related to the activities or "cost drivers" (administration, supervision, personnel, and so on), and the proportionate costs of each of these activities are added to the labor costs of the product or service. The basis is still the cost of labor productivity and is designed to illustrate the costs for absenteeism, safety, poor working conditions, and so on.

The cost-benefit analysis system to be outlined here was based on the work of Liukkonen[5] and incorporates some of the concepts of Activity Based Costing. This analysis was published by Oxenburgh[10] and since produced as a computer program.[11]

METHODS

The analysis is based on the cost of direct and indirect labor costs. These labor costs, prior to the changes, are compared with the predicted or actual labor costs following the intervention plus the cost of the changes.

A computer program[11] has been written that systematically presents the model and simplifies the arithmetic procedures involved in the cost-benefit analysis procedures.

Costs

The cost side of a cost-benefit equation is a series of items including monies paid to employees, taxation, and insurance; costs due to unplanned absences; and costs due to lowered production or quality. The costs can be expressed in any monetary units ($, £, etc.).

In cost-benefit analysis, the personnel, economic, and physical boundaries of the selected workplace have to be defined. The workplace selected can be a whole work site or a specific part of a work site, and the analysis has been used in workplaces employing from one person to several hundred people. When first using the model, the novice should start with a small, familiar workplace.

Table I shows the major headings, grouped for convenience into four blocks. The first group calculates the productive hours worked and paid for by the employer (hours worked per full-time equivalent employee per year). The second group calculates the wage and salary costs, and the third group includes the costs for labor turnover and training. The fourth group is used to calculate the productivity and quality losses due to injury and/or poor work methods and environment. The costs for Groups 2, 3, and 4 are expressed as the cost per employee per productive hour.

The data used can be retrospective or it can be based on predictions. Most commonly the cost data is retrospective, or what is happening now, and the benefits are based on predictions. This is the customary method for justifying capital expenditure.

To facilitate the collection and handling of data, a computer program (The Productivity Model[11]) has been developed. The computer edition of this model has 28 worksheets to cover these cost items, although in most cases the major costs will be derived from only 5 to 8 of the worksheets. Five to eight of the worksheets, which are the major costs will vary from workplace to workplace.

For a particular workplace, this first calculation of costs will give the base from which the economic benefits to be made from ergonomics interventions or improvements may be calculated.

Benefits

Once the base situation is established, the costs are reworked based

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

TABLE I. Major Headings and Description for the Cost-Benefit Analysis Worksheets

Group 1	
Productive hours worked and paid for by employer	■ Total paid hours per year for a full-time employee ■ Number of employees (full-, part-time, and casual) and hours worked in each category ■ Time taken for absences; vacation, training, illness, work-related injury
From these figures the productive time worked and paid for by the employer is calculated (hours worked per full-time equivalent employee per year).	
Group 2	
Wage and salary costs	■ Average wage paid to employees (full-, part-time, or casual at hourly or yearly rate) ■ Charges to wages including taxes, insurance, superannuation and pension, and special allowances (car, travel, entertainment, etc.) ■ Supervision, personnel, and administration costs including proportionate costs for supervision and management, personnel resources, and general overhead costs (e.g., proportion for head office)
The wage cost is calculated as cost per employee per productive hour.	
Group 3	
Turnover and training costs	■ Costs to employ new staff including administration, interviews, and advertising ■ Starting costs for selected new employees, including induction training, training on the job, training away from the job ■ Other costs, including lowered production/quality due to inexperience, and time taken by experienced staff to repair faults due to inexperience ■ Cost involved in loosing experienced employees (loss of skills and training)
The wage cost is calculated as cost per employee per productive hour.	
Group 4	
Productivity losses	■ Production/quality losses from, e.g., poor work methods, potentially injurious work conditions, and/or work conditions that leave workers incapable of their best performance ■ Costs include overtime and/or over-employment required due to absence and/or caused by the poor work methods or conditions ■ Other costs include the direct cost of loss of product, increased warranty costs, substitution, and an indirect cost: loss of customers
The wage cost is calculated as cost per employee per productive hour.	
Calculation: Groups 2, 3, and 4 are added together to give the actual wage cost per employee per productive hour.	

on the observed or predicted effects of the intervention.

It is necessary to rework only those parts of the model (the worksheets) where gains are expected. For example, if there is to be a reduction in manual handling, this may have expected benefits in lowered absence, reduced employee turnover, and lowered insurance premiums due to reduced injury rates. There may also be benefits due to reduced overtime and increased productivity. Only those worksheets itemizing these points need to be changed.

The costs for the intervention must also be included in the analysis. These costs may include capital expenditure, loss of production during the change-over period, training, and so on; in most companies cost methods for expenditure are well established.

The difference between the base calculations and the anticipated changes gives the expected benefits. The net benefits must take into account the productive time (hours per employee per year, from Group 1) and the number of employees in the selected workplace.

There are limitations in predicting the future, especially for interventions for ergonomics and health and safety reasons. There are no models on which to base assumptions that differ from engineering projects, where the predictions are based on established models and procedures. However, there are past ergonomics and health and safety interventions to call on, and experience may be gained by taking a previous intervention and looking at its costs and benefits.

In most interventions there are several ways to obtain a solution; which one is the most suitable will depend on, for example, a compromise between the extent to which the problem is resolved and its cost to do so. With a cost-benefit analysis, the costs of alternative interventions may be estimated and the most suitable one selected.

Pay-Back Period

The basis of the cost analysis is the cost per employee per productive hour. Group 1 is expressed as productive hours worked per year per employee, and it is used as the basis for the cost analyses in Groups 2, 3, and 4. Thus, the actual or productive labor costs are converted into a monetary cost. The benefits are similarly treated.

The pay-back period is derived from the net expected benefits and the cost for improvements. Improvement costs, whether capital or organizational, are standard for each company and include cost for materials and equipment, labor costs, training, and reduced productivity while the new methods are implemented.

The pay-back period is the cost for improvements divided by the net benefits. If the cost for improvements is a one-off cost or is calculated as being paid for in a single year, the pay-back period is calculated in years or fractions of a year. Thus,

$$\text{pay-back period (years)} = \frac{\text{cost for improvements}}{\text{net benefits}}$$

This is a financial simplification, as it does not take into account many factors used in capital costing. Generally, it is a reasonable approximation, as the pay-back period in most ergonomics

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

interventions, in this author's experience, is less than one year, most frequently about six months.

The cost-benefit analysis may also be used as a sensitivity analysis to determine where the economic losses occur. For example, in a particular workplace is it absence or is it lowered productivity that is the main economic loss? The ergonomist may then use this analysis to determine if the proposed ergonomics improvements will address this particular loss. If it does, then it is more likely that the resources will be available for the improvements than if it does not.

CASE STUDIES

Two case studies will be shown to illustrate the way the cost-benefit analysis may be used.

A Small Manufacturing Company

In this manufacturing company certain small forgings had to be finished by hand. The small parts were held steady on the workbench in the left hand, and Carborundum™ cloth and small finishing tools were moved around the forgings by the right hand.

The physical effort required to hold and finish the forgings led to hand and arm tiredness and induced the workers to reduce the effort put into their work. This, in turn, led to poor quality finished products, a concomitant high batch reject rate by the customer, and thus high production and warranty costs for the jobbing company.

This system of work resulted in high musculoskeletal injury rates to the upper limbs of the workers, leading to high injury and absence rates and to very high workers' compensation insurance premiums.

The linked causes for the high injury rates and low quality were not identified by the manufacturer until an ergonomist was consulted. Once the ergonomist had clearly defined the problem as stress to the upper limb soft tissues, the staff engineer was able to arrive at a solution. The solution was a simple one and involved nothing more than using a potter's wheel. The forgings were locked in the central position on the wheel and this relieved the left hand from the static posture of gripping the forging still on the workbench. The turning action of the potter's wheel relieved the right hand from turning the tools and Carborundum cloth around the forging.

After the solution was implemented, the immediate results were an increase in quality and a concomitant reduction in batch reject rates. The long-term results were a reduction in injury costs due to lowered injury absence rates and reduced workers' compensation insurance premiums. The pay-back period, using the cost-benefit analysis program, was 1 month.

Use of the cost-benefit analysis in this case study is shown in Tables II–VI.

Benefits and Pay-Back Period

The cost/employee/productive hour fell from \$29.23 to \$20.85 after the introduction of the potter's wheel. This is the sum of the employee costs from Groups 2, 3, and 4 (\$21.83 + \$0.00 + \$7.40 = \$29.23) and (\$19.81 + \$0.00 + \$1.04 = \$20.85).

The net benefit in 1 year is the difference in the (cost/employee/productive hour between the base and the improved situations) times (the number of employees) times (the productive hours worked in the base situation).

That is: (\$29.23 – \$20.85) × 4 × 1670 = \$55,978

The cost for the improvements was \$5,000, which included the cost for the potter's wheels and the ergonomist's time.

Thus the pay-back period is 5000 ÷ 55,978 = 0.089 year, or about 1 month.

TABLE II. Example of a Small Manufacturing Company, Group 1: Productive Hours Worked and Paid for by the Employer[A]

	Base Situation Year 1 Hours/Employee/Year	After Changes (Potter's Wheel) Year 2 Hours/Employee/Year
Total paid time	2080	2080
Less paid absences (vacation, sick leave, etc.)	160	160
Less injury absence	250	80
Net productive hours/employee/year	1670	1840
Number of workers (average)	4	4

[A]The workplace selected was that part of the company that finished small forgings by hand and did not include the forge, administration, transport, etc. This table has been derived from Table I, Group 1. Gains were in reduction of time lost through injury. Increased productive time has been carried through to Table III.

TABLE III. Example of a Small Manufacturing Company, Group 2: Wage and Salary Costs[A]

	Base Situation Year 1 Dollars/Employee/Year	After Changes (Potter's Wheel) Year 2 Dollars/Employee/Year
Wage cost	24,960 (\$12.00/hour)	24,960
Charges to the wage (insurance, tax)	5,242	5,242
Supervisory and administration charges	6,250	6,250
Average wage cost/employee/year[C,D]	36,452	36,452
Average wage cost/employee/productive hour[B]	(36,452÷1,670) =21.83	(36,452÷1,840) =19.81

[A]As worker's compensation insurance premiums are not paid until the following year, the reduction in premium has not been included in the Group 2 calculations.
[B]Average wage cost/employee/productive hour is the average wage cost/employee/year divided by the net productive hours worked/year.
[C]Average wage cost is expressed in dollars but any currency unit may be used.
[D]Although there is no effect on the average wage costs there is increased productivity (reduced cost per productive hour) as more productive hours are worked due to a reduction in injury absences.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

TABLE IV. Example of a Small Manufacturing Company, Group 4: Productivity Losses

	Base Situations, Year 1 Dollars/Year	After Changes (Potter's Wheel), Year 2 Dollars/Year
Overtime	12,960[A]	360[B]
Lowered production	36,452[C]	7,290[D]
Total labor productivity loss for this workplace	49,412	7,650
Productivity loss/employee/productive hour[E]	(49412 ÷ 4 ÷ 1670) = 7.40	(7650 ÷ 4 ÷ 1840) = 1.04

[A]Base situation overtime calculated from a wage rate of $18.00/hour (time-and-a-half) with each of the 4 employees working 200 overtime hours/year. Of this 200 hours, 90% was for health and safety reasons (to make up for production lost due to the poor work methods) (18 × 200 × 0.9 × 4 = $12,960).
[B]After introduction of the potter's wheel, overtime fell to 50 hours/employee/year. Of that, 10% was to make up for production lost due to the work conditions (residual injury) (18 × 50 × 0.1 × 4 = $360).
[C]An estimated 25% of labor output (average wage cost $36,452 from Group 2) was lost due to the poor work (production) conditions leading to the high batch rejection rates (0.25 × 36452 × 4 = $36,452).
[D]Lost labor output dropped to 5% of total productive hours worked after introduction of the potter's wheel (0.05 × 36452 × 4 = $7,290).
[E]Calculated as the total productivity loss divided by the number of employees divided by the productive hours worked/year

A Large Workshop

The second case is from a large, engine maintenance workshop. The workshop productivity was very low due to poor workshop layout, old-fashioned methods, poor management, and a demoralized work force. The injuries were varied but mostly musculoskeletal to the low back and the upper limbs.

A newly appointed management, with the assistance of an ergonomist, identified the causes of the low productivity and from that determined the solutions. These lay in getting the work force involved in management decisions and involving them in better working methods and in new equipment design (improved management and work procedures). The methodology of these solutions, among other factors, lay in improving safety and reducing musculoskeletal stress. Although health and safety was crucial to the solutions, they were not identified as separate issues but as part of the workshop restructuring.

TABLE V. Example of a Small Small Workshop, Net Change in Costs; Summary of Tables II–IV

	Base Situation Year 1	After Changes (Potter's Wheel) Year 2
Group 1: Productive hours/ employee/year	1670 hours	1840 hours
Group 2: Wage and salary costs	$21.83	$19.81
Group 3: Turnover and training costs[A]	$ 0.00	$ 0.00
Group 4: Productivity losses	$ 7.40	$ 1.04
Cost/employee/productive hour	$29.23	$20.85

[A]Although there was a high labor turnover, management considered that the training costs were small as the employees were unskilled. Administration costs were absorbed into other costs. For this reason and in this particular example the training and turnover costs have been ignored. Including them would give a faster pay-back period but, as the pay-back period was so rapid in any case, the error in omitting the turnover and training costs is, in practice, negligible.

TABLE VI. Example of a Small Workshop, Pay-Back

Cost for ergonomist	$4000
Capital cost of equipment (potter's wheels)	$1000
Benefits in first year after intervention (see text)	([29.23-20.85] × 4 × 1670) = $55,978
Pay-back	(5000 ÷ 55987) = 0.089 years

Data for the calculation of the pay-back period included faster throughput of the engines, higher quality of finish, and a more productive work force. The lowered injury costs were also included in the calculation. Even though the overall costs of the changes were large, the pay-back period was only 4 months. The way that the cost-benefit analysis may be used in this case study is shown in Tables VII–XII.

Benefits and Pay-Back Period

The cost/employee/productive hour fell from $19.23 to $18.12 after the introduction of the improved work procedures. This is the sum of the employee costs from Groups 2, 3, and 4; ($17.27 + $0.15 + $1.81 = $19.23) and ($17.34 + $0.17 + $0.61 = $18.12).

In this example there were two types of financial benefits to the employer: (a) is the benefit due to the higher productivity per employee, and (b) is the benefit due to a reduced labor force, the wage savings.

For (a) the benefit in 1 year is (the difference in the cost/employee/productive hour between the base situation and the improved work procedure) times (the number of employees during the improved work situation) times (the productive hours

TABLE VII. Example of a Large Workshop, Group 1: Productive Hours Worked and Paid for by the Employer[A]

	Base Situation Year 1 Hours/Employee/Year	Improved Work Procedures Year 2 Hours/Employee/Year
Total paid time	2,080	2,080
Less paid absences (vacation, sick leave, etc.)	320	304
Less injury absence	15	7
Net productive hours/ employee/year	1,745	1,769
Number of workers (average)	105	90

[A]Derived from Table I. Small reductions occurred in lost time in paid sick leave and injury absences; labor force was reduced significantly due to the improved working conditions during Year 2. The workplace selected was the part of the company that maintained diesel locomotives, and did not include other workshops, administration, etc.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

TABLE VIII. Example of a Large Workshop, Group 2: Wage and Salary Costs

	Base Situation, Year 1 Dollars/Employee/Year	Improved Work Procedures, Year 2 Dollars/Employee/Year
Wage cost	21,840 ($10.50/hour)	21,840
Charges to the wage (insurance, tax)	3,494	3,494
Supervisory and administration charges; proportion of head office costs[A]	4,801	5,347
Average wage cost/employee/year	30,135	30,681
Average wage cost/employee/productive hour[B]	(30,136 ÷ 1,745) = 17.27	(30,681 ÷ 1,769) = 17.34

[A]Fixed costs of administration were higher per employee because of reduced number of employees after work situation improvement.
[B]Average wage cost/employee/productive hour is the average wage cost/employee/year divided by the net productive hours worked/year (from Group 1). In this example there were only minor improvements to the average wage costs because the improved work conditions had only a small effect on productive time.

worked in the base situation). This gives a conservative value for the benefit of higher employee productivity.

TABLE IX. Example of a Large Workshop, Group 3: Turnover and Training Costs

	Base Situation Year 1 Dollars/Year	Improved Work Procedures Year 2 Dollars/Year
Recruiting costs, advertising, etc.	17,016	17,030
Training costs[A]	10,776	10,822
Average wage cost/employee/ productive hour	0.15	0.17

[A]Includes loss of production while the new employees learned work methods, and loss of production by experienced workers to correct faulty work. There were about 12 new employees/year before and after introduction of improved work procedures.

That is: ($19.23 – $18.12) × 90 × 1745 = $174,326 (a)

For (b) the improved work procedures not only led to a safer workplace and higher productivity but also to a reduced number of employees. The labor force went down from 105 to 90 employees, and this must also be taken into account. The wage savings is the (cost/employee/productive hour for the base situation) times (reduced number of employees) times (the productive hours worked in the base situation).

TABLE XI. Example of a Large Workshop, Net Change in Costs: Summary of Tables VII–X

	Base Situation Year 1	Improved Work Procedures Year 2
Group 1: Productive hours/employee/year	1,745	1,769
Group 2: Wage and salary costs	17.27	17.34
Group 3: Turnover and training costs	0.15	0.17
Group 4: Productivity losses	1.81	0.61
Cost/employee/productive hour	19.23	18.12

That is: $19.23 × 15 × 1745 = $503,345 (b)

The net benefit in one year is (a) + (b) = $174,326 + $503,345 = $677,671.

The estimated cost for the improved work conditions included capital expenditure; time spent by management, engineers and employees discussing new methods; and loss of production while the new machinery was installed.

The cost for the improvements was $248,000 which, for the purposes of calculation, are assumed to be spent in one year.

TABLE X. Example of a Large Workshop, Group 4: Productivity Losses

	Base Situation, Year 1 Dollars/Year	Improved Work Procedures, Year 2 Dollars/Year
Overtime[A]	15,750	5,400
Lowered production[B]	316,418	91,123
Total labor productivity loss for this workplace[C]	332,174	96,523
Productivity loss/employee/productive hour[D]	(332,174 ÷ 105 ÷ 1,745) = 1.81	(96,523 ÷ 90 ÷ 1,745) = 0.61

[A]For the base situation, calculated from a wage rate of $15.00/hour assuming each employee worked 40 overtime hours/year. Of this 40 hours, 25% was to make up for production lost due to the poor work methods; this was an agreed factor after discussion between the manager and engineer (15 × 40 × 0.25 × 105 = $15,750). After introduction of improved procedures only 10% of overtime worked was to make up for production lost due to the work conditions. Pay and hours of overtime worked remained the same (15 × 40 × 0.10 × 90 = $5,400).
[B]An estimated 10% of labor output was lost due to the poor work conditions (figure agreed to by management that represented a best guess, as sufficient records were not kept.) Labor output loss included ergonomic factors such as poor workshop layout and unsuitable tools (30,135 × 0.10 × 105 = $336,418).
[C]Improved work procedures reduced loss of labor output by three-fold (management estimate) (30,681 × 0.033 × 90 = 91,123).
[D]The productivity loss/employee/hour is calculated as the total productivity loss divided by the number of employees divided by the productive hours worked/year.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com

The pay-back period is 248,000 ÷ 677,671= 0.37 year, or about 4 months.

TABLE XII. Example of a Large Workshop, Pay-Back

Cost for consultants, travel of employees, time spent on discussions, etc.	$ 23,000
Capital cost of equipment	$225,000
Benefits in the first year after the intervention (see text)	$677,671
Pay-back	(248,000 ÷ 677,671) = 0.37 years

Discussion and Conclusions

The cost-benefit analysis described here uses the concept of a pay-back period. This is a simplification of the complex finances required for large expenditures, but it is a convenient way for noneconomists to visualize finance. Generally speaking, a pay-back period of less than 4 years is considered a good investment. With a pay-back period of less than 1 year there is really no need to make more complex calculations of financial benefits and, in the author's experience, most workplace improvements have a rapid return on investment.

Two case studies are given to illustrate the method by which the financial benefits of a change in the workplace (an intervention) may be calculated. The actual costs involved have been simplified and grouped together to explain the method used more easily. It is quite instructive to take the examples and change some of the figures to see how this affects the end result, the pay-back period.

It is important when using such an analysis to understand where accuracy is required and where approximations are sufficient, or where some costs are not sufficiently important or large enough to be worth the effort to find them. Many cost factors are well hidden in a company and are not easily found; even more cost factors are not measured and recorded. Discussions with management and the "shop floor" (whether manufacture or service) will frequently give an approximate cost. That cost can be entered into the analysis and variations about that figure made to see how important its accuracy is to the final outcome, the pay-back period. Whether a pay-back period is 3 months or 6 months may be less important than the fact that both are very good returns on investment. Such changes to the analysis are easily made in the computer version.[11]

There are several ways by which a cost-benefit analysis may be used in the workplace. A cost-benefit analysis can be used after the completion of a program to see whether or not the workplace improvements were financially successful. In the first of the case studies, the improved condition (introduction of the potter's wheel) was initially to reduce the musculoskeletal upper limb injury rate and then to improve quality. In the second example, the improved condition was initially to increase productivity; this also had an effect on the injury rate. In both cases the pay-back period was short, so both were financially successful.

A cost-benefit analysis can be used as a sensitivity analysis. By inspecting the labor cost parameters, the areas where losses occur or the highest costs are incurred can be seen. In the first case study the major losses were in injury absence and in losses due to lowered production (product quality). In the author's experience it is not unusual for management to clearly see production losses but, at the same time, not to realize that absence rates can also severely dent profit. This was the experience of the small company.

A cost-benefit analysis may also be used to illustrate the potential benefit of a program for workplace improvement. In the second case study the injury rate was not high enough to stimulate management into controlling injuries above their present activities, but the productivity was so low that productivity clearly required improving. Interestingly enough, it was not that the poor production methods led to poor quality of output, as in the first case, but to a low rate of productivity. This is shown in Table X (the base situation column) where management estimated the labor productivity losses due to poor working conditions at well over $300,000 each year. The savings in this category alone would have paid for the cost of the improvements in about 1 year.

Acknowledgments

The author would like to acknowledge the assistance given by Dr. P. Liukkonen (Stockholm), and to Mr. D. MacLeod (Minnesota) and Mr. G. Popple (Sydney) who supplied the data for the case studies.

References

1. **Bequele, A:** The costs and benefits of protecting and saving lives at work: some issues. *Int. Labour Rev. 123*:1–6 (1984).

2. **Oxenburgh, M.S. and H.H. Guldberg:** The economic and health effects on introducing a safe manual handling code of practice. *Int. J. Ind. Ergonom. 12*:241–253 (1993).

3. **Snook, S.H.:** The costs of back pain in industry. *Spine: State Art Rev. 2*:1–5 (1987).

4. **Andreoni, D:** *The Cost of Occupational Accidents and Diseases. (Occupational Safety and Health Series, 54)* Geneva: International Labour Office, 1986.

5. **Liukkonen, P.:** *Se och Räkna pa Arbetsmiljön [Inspect and Calculate the Work Environment].* Stockholm: Arbetarskyddsstyrelsen, 1990. [Swedish]

6. **Parenmark, G., A.-K. Malmkvist, and R. Örtengren:** Ergonomic moves in an engineering industry: effects on sick leave frequency, labor turnover and productivity. *Int. J. Ind. Ergonom. 11*:291–300 (1993).

7. **Helander, M.G. and G.J. Burri:** Cost effectiveness of ergonomics and quality improvements in electronics manufacturing. *Int. J. Ind. Ergonom. 15*:137–151 (1995).

8. **Dahlén, P.G. and S. Wernersson:** Human factors in the economic control of industry. *Int. J. Ind. Ergonom. 15*:215–221 (1995).

9. **Dahlén, P.G.:** "Labor stability in the justification of advanced manufacturing systems." Ph.D dissertation, Lund University, Lund, Sweden, 1995.

10. **Oxenburgh, M.:** *Increasing Productivity and Profit through Health & Safety.* North Ryde, NSW, Australia: CCH International, 1991.

11. **Oxenburgh, M. and Fenestra Software:** The Productivity Model [Computer software] 1993. Distributer, Dr. M. Oxenburgh, 77 Ryan St., Lilyfield, NSW 2040, Australia; fax +61 2 9818 4193; e-mail 100400.1620@compuserve.com.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission. www.manaraa.com