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Editorial

On the cost-effectiveness of ergonomics

1. Introduction to the special issue

There has been a perennial call for ergonomics to demonstrate that it is good value for money. While it may seem self-evident to ergonomists that their work is of value and real benefit, such a view reflects their particular view of the world and might not be shared by the 'unenlightened'. Ergonomists in professional practice will be a familiar with the question of "Why should I use Ergonomics?" (or more likely, "why should I pay for Ergonomics?") from a doubting client. Responses from the ergonomists' 'world-view' might range from the improvements to efficiency to the reduction in risk, and cover a considerable set of arguments raised by legal, moral and ethical issues for employing Ergonomics. The fact that such arguments might not cut the ice in the business world suggests that we need to be able to present a strong business-case first, and then underpin this with an appeal to broader issues with which ergonomics is more familiar. In this special issue, the focus will be on the financial and business-case, arguments for employing ergonomics. From the papers presented in this special issue, the intention is to provide a set of models for preparing business cases and a set of supporting evidence to demonstrate the value of ergonomics.

Whilst it may seem obvious that Ergonomics is cost effective to those in the profession, actual proof is hard to come by. Having said that, the number of cases showing financial benefits of ergonomics is growing. One of the classic studies on the cost-effectiveness of Ergonomics comes from the rear centred, high-mounted, brake light on automobiles (McKnight and Shinar, 1992; Akerboom et al., 1993). As the reader will probably recall from the original study conducted in the USA in the mid-1970s, 2100 taxicabs were tested with four brake light configurations (including the rear centred, high-mounted, brake light) with the purpose of determining if any of the configurations reduced the incidence of rear-end collisions. The results showed that taxicabs fitted with the rear centred, high-mounted, brake light configuration experienced a 50% reduction in rear-end collisions. Similar findings were produced for a study of 5400 passenger cars owned by a telephone company. Cars fitted with the rear centred, high-mounted, brake light experienced a substantial reduction in the number and severity of rear-end collisions. For both the taxicab and the passenger car studies, the effects of reduced collisions were most pronounced in the hours of darkness. It is argued that the rear centred, high-mounted, brake light offers several perceptual advances from convention brake lights. First is the principle of separation: the braking function is separated from the lighting function. Second in the principle of focal viewpoint: the brake light is presented in the centre of the drivers' visual field. Third in the principle of prediction: the driver can see vehicle braking ahead of the vehicle directly in front and can anticipate the need to brake. Researchers estimated that some 900,000 accidents would be prevented with savings of approximately $434,000,000 per year in car repairs. With costs of $15 per car for fitting the brake light, the overall savings were estimated at around $400,000,000. On the basis of this research, changes in legislation in the USA required all new cars to be fitted with the rear centred, high-mounted, brake light after 1 September 1985. Subsequent studies on rear-end collisions in 11 states in the USA have shown that the rear centred, high-mounted, brake light is particularly effective in preventing chain collisions (i.e., collisions involving three or more vehicles). This reinforces the effectiveness of the 'principle of prediction' in design. Follow-up studies have also found that the costs were smaller, and the benefits were greater, than anticipated. Actual costs of the brake light turned out to be around $10 per car and an annual saving estimate is closer to $900,000,000. If all ergonomics interventions were this clear cut, we would not need a special issue on the cost-effectiveness of ergonomics.

In a recent issue of The Ergonomist (September 2002), Tina Worthy (Editor of The Ergonomist) collected a series of case studies to illustrate how effective ergonomics was in producing financial savings in terms of reduction in loss and wastage, improving productivity, and reducing accidents. These savings are reproduced in Table 1.

In case study one, changes to the bin height were accommodated to prevent excessive bending and reaching. This resulted in reductions in task time and product spillage. The costs of implementing the changes were

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Table 1
Payback period for ergonomics interventions

Case study	Intervention strategy	Cost $k	Saving $k	Payback period
1	Changes to bin height	14	294	2.5 weeks
2	Changes to feeder/conveyer	4.7	37.5	6.5 weeks
3	Extended conveyer	9	492	1 week
4	Fit CCTV to lorries	51	144	18 weeks
Average		£19.8 k	£241.9 k	7 weeks

recouped in 2.5 weeks. In case study two, raising the product feeder and conveyer and the addition of a product feeder also reduced task time and product wastage. The costs of the changes were paid back by productivity improvements within 6.5 weeks. In the third case study, an extension to the conveyer to fully utilise all of the space in the working area increased productivity and was paidback within 1 week. In the final case study, closed circuit television (CCTV) cameras were fitted to the back of lorries in order to reduce accidents when reversing vehicles. Drivers were able to see what was behind them by viewing an in-cab monitor connected to the CCTV. The costs of fitting the CCTV were recouped through reductions in accidents within 18 weeks.

It is worth pointing out that, on the basis of these four case studies, the total savings brought about by the ergonomic interventions was over $950,000 and the cost of implementing the savings were less than 10%. This evidence conveys the general message of the special issue. It is also worth noting that, while the changes themselves are all simple and relatively easy to implement, the role of ergonomics in implementing and motivating these changes should be clear; without a clear appreciation of both the potential risk of working practices and a clear proposal of how to reduce such risk, it is unlikely that the changes would have been considered, let alone implemented. This raises one of the common problems that ergonomics faces: by only considering the solutions, people might mistakenly assume that the changes proposed are 'obvious and simple. It is the duty of ergonomics to tackle the assumption that we are in the business of peddling 'common-sense' and to provide stronger arguments for the analysis that underlies the sort of changes outlined in Table 1.

2. Contributions to the special issue

The routes to demonstration of cost-effectiveness vary considerably, as demonstrated by the contributions to this special issue. Some authors have demonstrated by way of case study, some by developing a business-case model, and some by a balance sheet approach. All of the contributions selected for publication in the special issue help to develop the case that Ergonomics interventions offer considerable benefits to the organisation in question, and these benefits include quantifiable, financial, outcomes.

Before starting with the papers accepted for the special issue, it is worthwhile revisiting the original cost-effectiveness paper by Beevis and Slade (1970) published in Applied Ergonomics in its first volume. This is a seminal scene-setting paper, and the benchmark by which we may judge progress of the discipline in developing the argument for cost-effective ergonomics. To this end we have requested that the paper be reprinted in its original form, and it is the first paper in the special issue. In their original paper, Beevis and Slade argued that there was barely any evidence that justified ergonomic interventions on a financial basis. They proposed that justification for improvement in human-machine systems performance, although necessary, is not sufficient without supporting cost–benefit analyses. In 1970, they found less than 20 examples that represented the entire corpus on cost–benefit studies in ergonomics. These examples demonstrated improvements in productivity through better equipment design, reductions in mistakes and accidents, improvements in the design process through reduced time from concept to production, and increased sales through better designed products. What evidence they had was positive about the financial implications of ergonomics, there was just not much of it at the time. In addition, they spotted a contradiction in the way in which this evidence was uncovered. In order to find out if ergonomics interventions were cost effective, before and after intervention measures were taken and the savings (or loss) were accounted. This is an unsatisfactory position for any organisation faced with implementing changes. Ideally, the costs and savings should be identified before the decision to implement the changes are made. One measure of the maturity of the discipline is how far we have come in identifying the costs and savings a priori. Around a decade later, Kragt's (1992) book on Enhancing Industrial Performance described a dozen or so studies that reported ergonomic intervention and some of which the potential financial benefits arising from these interventions. Interestingly enough, there was still some variation in how costs and benefits were accounted. Perhaps rather disturbingly, the papers in this special issue demonstrate that, as a discipline,

ergonomics has *still* to determine how best to represent such fundamental data as cost of implementation and financial benefits accrued from the implementation.

In the first of the new papers, Hendrick argues that professional ergonomists need to put their proposals for ergonomic interventions in economic terms. This is especially true when they are trying to convince the business community, there is a need to speak the same language, as decisions regarding change may be rationalised on a financial basis. To assist in this approach, Hendrick outlines what the likely costs and benefits will be in an ergonomic intervention. This analysis may serve as a template for any ergonomic intervention. Under the cost side of the balance sheet he identifies: personnel costs, equipment and materials, disruption to normal working, and overheads. Under the savings side of the balance sheet he identifies: increased productivity, reduced errors and accidents, reduced training, reduced maintenance, reduced materials and equipment, and improved image of the company. To reinforce the need for an early ergonomics intervention, Hendrick presents a sliding scale of costs to illustrate how cost increase the later the ergonomics intervention. He estimates that this ranges from 1% of total project budget in the design and development programme to over 12% of the total budget by the time that normal operations have been established. Despite the relative merits of the ergonomic balance sheet, Hendrick identified other factors that are implicated in success of ergonomic interventions. These factors include: management commitment, participation in ergonomics, integration with other improvement programmes, and so on.

The business case model is proposed by Seeley and Marklin, who point out that corporate managers may not always understand the relationship between an ergonomic intervention and financial benefits to the company. This paper also argues that ergonomics has to learn the language of business in order to put its case in the most effective manner. By way of an example, Seeley and Marklin present the case of ergonomic interventions for overhead electrical line workers. The work of overhead electrical line workers is physically demanding and has a high number of injuries. These injuries lead to lost work days and restricted duties, putting even more pressure on those left working. Seeley and Marklin report that around 66% of overhead electrical line workers present with severe symptoms of muscoskeletal disorders. This ought to be an area where an ergonomics intervention could make dramatic improvements. Seeley and Marklin hypothesised that by replacing the manual wire cutters and presses with battery-operated versions of the same, they could reduce or eliminate many of the risk factors causing some of the muscoskeletal disorders experienced by overhead electrical line workers. In order to convince corporate managers of the benefits of the ergonomic intervention, Seeley and Marklin developed a detailed breakdown of the costs associated with the purchase of the battery-operated wire cutters and presses and the savings from reduced medical costs, personnel replacement costs, and training costs. On the basis of their analysis, they were able to demonstrate that the capital costs would be recouped within 4 months.

Kirwan reports on a case study of ergonomics in the design and development of a thermal oxide nuclear reprocessing plant in Sellafield at West Cumbria in the UK. The cost of the ergonomics programme at around £1,000,000 was seen as an acceptable cost of ensuring safety. The ergonomics interventions addressed nine area, as shown in Table 2.

Kirwan describes the methods used in the ergonomics programmes which are summarised in Table 2. He also indicates the relative impact of the ergonomics intervention and the effort required. This offers a qualitative cost–benefit analysis of the different areas of the programme. Although no formal analysis of the saving brought about by ergonomics are presented, Kirwan argues that the cost of not investing in ergonomic in a safety-critical industry are beyond contemplation. Perhaps were the case is so clear-cut, as previous accidents

Table 2
Summary of the ergonomics programme at Sellafield

Method\area[a]	Inter	Proc	Train	Maint	Staff	Emerg	Mgmt	Infor	Risk
HTA									
Error analysis									
Scenario analysis									
Timeline analysis									
Checklists									
CAD models									
Guidelines									
IMPACT	High	Low	Med	Med	Low	High	Low	Med	High
EFFORT	High	Low	Low	Med	Low	Med	Low	Low	High

[a] Key to area: Inter = Interface, Proc = Procedures, Train = Training, Maint = Maintenance, Staff = Staffing, Emerg = Emergencies, Mgmt = Management, Infor = Information, Risk = Risk Assessment.

can testify to, there is not so much pressure to make a formal business case.

Sen and Yeow conduct a study to show whether or not ergonomic interventions can prove cost-effective in the developing countries. Prior to their intervention the manufacture of electronic motherboards was proving troublesome. Low productivity and low quality production led to high number of rejections and poor moral in the employees. Sen and Yeow used a variety of method in order to determine the cause of the problems, such as: walkthroughs, direct observation, interviews, questionnaires, and video recording. On the basis of these analyses, process mapping revealed five main stages in the production of motherboards: solder paste depositing, surface mounted component placement, manual soldering, manual cleaning, inspection and test. According to Sen and Yeow, many of the problems encountered through these stages were due to poor initial design of the motherboard. Ironically, computer-aided design functions, such as snap-to-grid, caused the designer to introduce design flaws in the motherboard leading to many of the problems found in manufacture. Redesign of the motherboard led to dramatic improvements in the quality of the motherboards and consequently improvements in productivity and reduction in rejections. Sen and Yeow estimate that the improvements led to savings of over $500,000 in the first year. The costs of the intervention were less than 2%, making this an extremely profitable proposition for the organisation.

MacLeod argues for an amalgamation of results from diverse ergonomics methods, proposing the idea of triangulation on qualitative and quantitative data. As an ex-navigator, MacLeod uses the metaphor of plotting a way through the ergonomics intervention, from the position prior to the intervention, to the desired position. Triangulation of data from a variety of sources is offered as a way of reducing error (thereby increasing accuracy) in the statement of the problem and in the proposal for the intervention. MacLeod argues that it can be difficult to estimate all of the financial benefits that might be gained through ergonomics interventions. Rather he offers a consideration of the broader issues of ergonomics effectiveness. In particular, he cites that failure of technology to live up to the expected benefits. Rather he argues that it is ergonomics, not technology per se, that will enable those benefits to be forthcoming. For this MacLeod develops the concept of fitness-for-purpose to argue that the utility of a system is the degree to which it meets the goals of usability, reliability and performance. Although he does not present a financial balance sheet for ergonomics, MacLeod claims that the costs of ergonomics interventions are typically "*minuscule when compared with overall programme costs*".

Stanton and Young take a different tack, rather than looking at ergonomics interventions by expert ergonomists, they consider the degree to which ergonomics methods can be used effectively by non-ergonomists. The idea of enabling professionals from other disciplines to acquire and use ergonomics methods is well-established in the applied domain. The methods vary considerably in their complexity and skill required to use them effectively. In their study, Stanton and Young trained a population of engineers in ergonomics methods and subsequently assessed the effectiveness of the engineers application of the methods to the evaluation of a device. Using the twin metrics of reliability and validity, Stanton and Young were able gauge which methods could be applied with relative ease and which methods required more practice. Stanton and Young also develop a method for utility analysis of ergonomics interventions. The approach uses financial data together with the reliability and validity values to determine the cost-effectiveness of ergonomics methods in product design. Whilst the formula and the data are in the early stages of development, it does point the way to a more formal assessment of cost-effectiveness. In its present form, Stanton and Young caution that relative, rather than absolute, values might be the most credible approach.

In the final paper, Beevis revisits the cost–benefit case for ergonomics. In reference to the original Beevis and Slade (1970) paper, the initial challenge for an ergonomics business case was laid down. In the new paper, Beevis shows that despite some 1300 papers citing cost-effectiveness or cost–benefit of ergonomics, most report on the cost of the intervention rather than on the savings brought about. Beevis argues that identifying the savings is difficult because they are often invisible. He also suggests that commercial organisations are more interesting in curing problems than formally identifying the cost and savings brought about by the intervention. This suggests that if the corporate managers are acutely aware of the problem, then they may not press to hard for a business case model. If the ergonomics intervention looks less pressing, it may require the business case model to convince them of the need to intervene. It is unlikely than an organisation would support the costs of collecting the data to prove that the ergonomics intervention was cost-effective after the fact. To suggest such a proposal may actually put them off. The business case model developed by Beevis identified three main categories for financial information: costs saved (including correct identification of underlying problem rather than wasting money addressing the wrong problem, increasing productivity, reducing injury, improving morale, increasing competence, etc.), cost avoided (including loss of sales, increased training, increased support and maintenance, increased rejection rates) and new opportunities (including flexible systems design, expanded markets for business, and broader range of users). Compared to these savings, the cost of an

ergonomics intervention is likely to come out quite favourably. Beevis is also keen to point out that other disciplines have difficulties in making a business case, this problem is not unique to ergonomics. Against this background, we should be a little more bold in estimating the value of interventions that we provide.

3. Conclusions

The contributions to this special issue have argued that we are now in possession of sufficient knowledge to be able to construct a sound business case for ergonomics interventions. The form of the business model, and its constituent ingredients, are presented. All of the papers suggest that the costs of ergonomic involvement and intervention are likely to be a small fraction of the total budget. Figures ranging from 1% to 12% were cited with payback periods of less than 1 year. This presents a very optimistic picture for ergonomics.

Quite apart from the legal, ethical and moral aspects of ergonomics, the question to pose is not whether an organisation can afford ergonomics, but rather whether the organisation can afford not to have ergonomics. Support from a credible business case model should show exactly what all the visible and invisible costs and saving are. The business case model can bring many of the hidden savings into an open light. Furthermore, while the idea of cost: benefit might appear to be particularly relevant to the consultants whose business it is to provide ergonomics solutions, it is our belief that *all* members of the ergonomics community should begin to consider the economic implications of their work. To paraphrase Hendrick, ergonomists might not be economists, but ergonomists need to speak the language of business in order to justify ergonomic interventions. Methods for achieving this are presented in this special issue.

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