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Paul Lanoie, Sophie Tavenas

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COSTS AND BENEFITS OF PREVENTING WORKPLACE ACCIDENTS: THE CASE OF PARTICIPATORY ERGONOMICS

Paul Lanoie[†], *Sophie Tavenas*[‡]

Abstract / Résumé

This paper provides a cost-benefit analysis of a participatory ergonomics program conducted at the beginning of the 1990s to reduce back-related disorders among packers at a warehouse of the Société des Alcools du Québec in Quebec City. After evaluating the costs of the program, we present a rigorous econometric analysis to assess how many accidents have been prevented by the program so as to compute the direct and indirects costs avoided as a result of such accident reduction. We show that the program has indeed been profitable for the firm.

Les auteurs de cet article ont effectué l'analyse coûts-avantages d'un programme ergonomique mis en oeuvre en 1990 pour diminuer, avec la participation des intéressés, les problèmes liés aux maux de dos chez les manutentionnaires d'un entrepôt de la Société des Alcools du Québec situé dans la ville de Québec. Après avoir estimé les coûts du programme, ils ont conduit une analyse économétrique rigoureuse pour déterminer le nombre d'accidents évités grâce au programme. Ils ont pu ainsi calculer les coûts directs et indirects qui n'auront pas à être subis à cause de la réduction du nombre des accidents. Ils en concluent que le programme a réellement été rentable pour la S.A.Q.

[†]Écoles des Hautes Études Commerciales et CIRANO

[‡]Écoles des Hautes Études Commerciales

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Table of Contents

1. Introduction

The social cost of workplace accidents is considerable. In a typical year in the United States, more than 50 times as many working days are lost to work injuries as to labour strikes, and from one-half to one-third as many working days are lost to work injuries as to unemployment (Krueger, 1988). In Quebec, the compensation paid to occupational-accident victims increased from $415.04 million in 1981 to $650.5 million in 1993 (1993 Canadian $), while the cost of medical assistance for such victims rose from $126.74 million in 1980 to $128.9 million in 1993.[1] It is noteworthy that back-related problems account for about one-third of these expenses (CSST, 1989).

Of course, the expenses referred to above represent only the direct costs of workplace accidents and do not include the indirect costs that are also borne by firms. These include expenses related to interruption of the production process, mechanical breakdown or the training of a substitute worker. The literature that has tried to measure these indirect costs has shown that they are at least as great as the direct costs.[2]

Whether the total costs of workplace accidents are too high, or are higher than their optimal level, remains an open question. Still, there seems to be a certain consensus that a reduction of the costs related to occupational accidents would be desirable (for instance, Quebec occupational health and safety law[3] recommends that firms totally eliminate risk in the workplace).

One way to reduce these costs is to put more emphasis on policies to prevent job-related accidents. And firms will adopt these policies more readily if managers are convinced that they are worthwhile financially. In other words, more information is required on the costs and benefits for individual firms of prevention programs. The costs usually include investments in safer equipment and time to implement the program (e.g. training), etc., while the savings in direct and indirect costs resulting from the prevented accidents represent the main benefits.

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[1] See the annual reports of the Commission de la santé et de la sécurité du travail (CSST).

[2] See, for instance, Brody *et al.* (1990).

[3] Act respecting occupational health and safety, section 2.

This paper partly fills this gap by providing a cost-benefit analysis of an accident-prevention program adopted by a Canadian firm.[4] The program is a participatory ergonomics project conducted at the beginning of the 1990s to reduce the incidence of back-related disorders among packers in a warehouse of the Société des Alcools du Québec (S.A.Q.) in Quebec City, Canada. Participatory ergonomics is a promising new approach whereby the main principles of ergonomics are taught to workers so that, drawing on their own experience, they can suggest personal solutions to work-related safety problems.[5]

As will be discussed in greater detail below, a certain number of cost-benefit analyses of prevention programs have already been published. To the best of our knowledge, this paper provides the first cost-benefit analysis of a participatory ergonomics program. It is also innovative in presenting a rigorous econometric analysis to evaluate the program's impact on the accident rate, while previous studies assess in a more subjective manner the reduction in accidents due to the prevention program that they investigate (see section 2).

The rest of the paper is organized as follows. Section 2 briefly presents the literature on cost-benefit analyses of accident-prevention programs. Section 3 describes more fully the basic principles of participatory ergonomics, and how they were applied at the S.A.Q. Section 4 evaluates the major costs of the program. In Section 5, we first present the econometric analysis that assesses how many accidents have been prevented because of the program and then the savings in terms of direct and indirects costs avoided as a result of such accident reduction. These are the main benefits of the program. Section 6 provides a comparison of the program's costs and benefits, in which it is shown that it has been profitable for the firm. Finally, Section 7 discusses the limitations of our study and the avenues for future research in this area.

2. A Brief Survey of the Literature

We surveyed four studies that have performed a cost-benefit analysis of a prevention program aimed at job-related accidents. Two of these programs are related to ergonomics, and we shall present them last.

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[4] The term "cost-benefit" analysis is used here rather loosely. Strictly speaking, a cost-benefit analysis identifies the costs and benefits for society as a whole, and flows of costs and benefits are actualized with a "social" rate of discount. Here, we are concerned with a financial analysis of the costs and benefits for the firm, using its own discount rate. Of course, this is a major component of an eventual cost-benefit analysis for society, and we therefore use the term cost-benefit analysis in this text.

[5] This paper is part of a multidisciplinary research effort to evaluate the program. Other aspects of the program were studied by an ergonomist and two specialists in socio-dynamic aspects of working conditions.

First, Harms-Ringdhal (1990) provides a cost-benefit analysis of prevention programs introduced at four different firms (three of them in the pulp and paper industry, and the other in the sanitary industry). These prevention programs include improved accident investigations, safety analysis in the design of new equipment, and purchase of safer machines.

The researcher is able to establish that these programs have contributed to a reduction in workplace accidents and, of course, to a reduction in the costs related to such accidents. To identify the reduction resulting from prevention, Harms-Ringdhal interviews a number of managers at each firm. When the managers disagree on the magnitude of the reduction, he provides a sensitivity analysis using the estimates provided by various managers. He concludes that these prevention programs involve more benefits than costs.

The study by Bertrand (1991) is similar. His analysis is based on the prevention policies adopted by two plants operated by a firm in the Quebec's wood industry. These policies include training foremen, meetings between foremen and workers to make the workers more sensitive to the issue of safety in the workplace, and investments in protective devices for individual workers and in safety features for machinery. He also interviews managers and foremen to determine the reduction in accidents that can be attributed to prevention policies, and concludes that they are worthwhile financially.

Third, Drury *et al.* (1983) examine the ergonomic and economic efficiency of a lever to make it easier to pack pallets as a measure to reduce injuries among packers. The evaluation is done in a laboratory with five packers. Their simulation shows that the lever reduces cardiac frequency and back-related stress, thus improving workers' endurance by a factor of three and reducing the probability of injury by a factor of four. With general information on the costs of back injuries, they demonstrate that, given the induced reduction in the probability of back disorders, the use of the lever would be profitable for firms.

Lastly, Spilling *et al.* (1986) show, from a case study on a Norwegian telecommunications firm, that ergonomic principles applied by an ergonomist to improve work stations have been profitable for the company. These improvements have reduced absenteeism at the firm and its turnover rate. Such reductions related to the ergonomic program have been assessed through interviews with workers. The authors were able to evaluate the savings induced by these improvements.

This brief summary shows that, despite the growing popularity of participatory ergonomics, this measure has never been evaluated by means of a cost-benefit analysis. Furthermore, a crucial aspect of such a cost-benefit analysis, i.e. determination of accident reduction resulting from a prevention program, has never been tackled with the rigorous tools of econometric analysis. Although Drury *et al*.

have used a simulation, it is well known that results obtained in a laboratory and in a "real-world" situation may be quite different.[6]

3. Description of the Program

Ergonomics is the study of the relationship between workers and their environment, especially the equipment they use. Participatory ergonomics is an innovative field requiring that the main principles of ergonomics be taught to workers so that, by drawing on their own experience, they can suggest their own solutions to work-related safety problems.

In the past, ergonomics has proved useful to help prevent back-related problems. These problems are frequent among warehousemen. The program under study in this paper took place at a warehouse of the Société des Alcools du Québec (S.A.Q.). Before we describe the program in detail, it is instructive to say a few words about the enterprise.

The S.A.Q. has a monopoly over the distribution of wine and spirits in the Canadian province of Quebec. It sells 3,400 products at about 350 branches throughout the province. The S.A.Q. buys these products from more than fifty countries. When the bottles arrive in Canada, they are sent to two distribution centres, the Centre de distribution de Québec (C.D.Q.) and the Centre de distribution de Montréal (C.D.M.), and from there they are dispatched to the different branches. The work at these warehouses consists mainly of putting together the products required by the different branches. It involves the regular handling of boxes containing bottles of wine and spirits, and the boxes are circulated mainly in the warehouse on wooden pallets with forklift trucks and pallet trucks. The warehouse has four main departments: receiving, preparation of orders, shipping and delivering.

At the end of the 1980s, it was felt that back disorders were too frequent among warehousemen at the Centre de Distribution de Québec (see Table 1), and it was decided that a participatory ergonomics project would be implemented to reduce the incidence of these accidents. In 1989, a contract was signed between the S.A.Q., its union and a team of ergonomists (researchers and practitioners) from the Institut de recherche en santé et sécurité du travail (IRSST), setting forth the broad outlines of a program for the C.D.Q.

A joint working committee (with union and management having equal representation) was put together in the fall of 1989 to implement the program. The members of the

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[6] See, for instance, the work of Peltzman (1975), who shows that, from simulations, engineers thought that the new safety devices added to cars at the beginning of the 1970s would be much more effective in reducing the fatality rate than they turned out to be.

group received five days of training in the main principles of ergonomics and participatory ergonomics in January 1990. Furthermore, the group was to meet once a week to discuss the different safety problems at the C.D.Q. and their solutions. Unfortunately, a strike occurred from October 1990 to March 1991. During the strike, most of the work at the C.D.Q. was done by S.A.Q. managers; when the workers went back to work, it is fair to say that most of their demands had not been met.[7] The committee ceased its work during the strike, after which the program was the responsibility of the official joint work site safety committee.[8]

Six principal problems were addressed as a result of the recommendations made by the committee.[9] First, an **automatic pallet distributor** was bought. Before this purchase, workers often had to take a heavy wooden pallet from the top of a high stack to install it on their pallet trucks. This activity involved movements that were painful and dangerous for the back. With the new device, the workers do not have to make any effort and the operation is faster. The distributor was bought in June 1991.

Second, on the committee's recommendation, **new pallet trucks** were designed so as to be better adapted to the size of the worker, to reduce his energy expenditure and to improve his posture. Two of these redesigned pallet trucks were bought at the end of 1990. The changes suggested by the workers at the Quebec warehouse (C.D.Q.) were also taken into account by the Montreal warehouse (C.D.M.) when they bought new pallet trucks.

Third, the committee was concerned with the problem of **stuck boxes**. Boxes are stuck together on the pallet so they will be more stable during transportation. The special glue used for this operation is supposed to be biodegradable so that, when the products arrive at the warehouse, the boxes can be handled easily. Still, the glue often has not biodegraded, so that the workers have to make an extra effort to unstick and handle the boxes. Sometimes, the stuck boxes are torn during handling, and the bottles fall and break. Different solutions were suggested to this problem. First, the pallets with stuck boxes were identified, so that the workers could adjust their effort to the boxes. Second, the problematic suppliers were identified and approached so that they could help identify a solution. It was found that more than half of the problem was due to one supplier. Representatives of that company came to Quebec to discuss different solutions with the committee, such as changing the type of glue or

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[7] This impression was obtained from conversations with workers and managers at the C.D.Q.

[8] In Quebec, such committees are compulsory at firms with twenty or more employees. Half of their members must come from the union and the other half from management.

[9] Other problems were addressed, such as the handling of wine barrels, but it was felt that they were too negligible, in terms of costs, to be treated. Their inclusion would not change the nature of the conclusions reached in this analysis.

the type of cardboard used for the boxes. The problem with that company was finally solved in 1991.

Fourth, there was a problem concerning the **wrapping** of the pallets. Another way to keep the boxes stable on the pallet is to wrap them all together. This was done for the pallets that the C.D.Q. ships to the different branches of the S.A.Q. Before 1993, this operation was done manually by workers who walked around the pile holding a Saranwrap roll. This task was particularly painful. It made the workers feel dizzy and could be harmful to their backs if the pile on the pallet was high. The C.D.Q. therefore decided to buy an automatic wrapper. The machine arrived in 1993.

Fifth, the C.D.Q. truckers often suffered from back-related problems because their **truck seat** was poorly designed. The committee suggested that new trucks with ergonomic seats be purchased. Two new trucks with such seats have been bought since the suggestion was made.

Lastly, a new **glove** was designed to facilitate handling of the boxes and to reduce risks for the hands. The workers were then equipped with such gloves. As one can see, participatory ergonomics did not lead to major changes in the warehouse. It will prove interesting to know whether these changes were worthwhile.

4. The Costs of the Program

In this and the following sections, we will describe and compute the program's costs and benefits. Two scenarios will be considered. First, we will state the costs and benefits to date; the last year for which complete information is available is 1993.[10] Second, we will assume that the impacts of the program will last at least five years, so that we will add to the total costs and benefits realized until now the projections of these costs and benefits for the next five years.

All the costs are reported in Table 2 according to our two scenarios.[11] These costs are related to the different elements of the program as they were described in the preceding section. First, there are the costs related to training the committee members, and the costs of their meetings. This is essentially a cost in time lost measured by the wages (including fringe benefits) of the participants for the hours spent on the activities related to the program. Note that the time spent by the managers on

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[10] We refer to the S.A.Q.'s fiscal years. In fact, the year 1993 extends from July 1, 1993 to June 30, 1994.

[11] For the second scenario, projections of the inflation rate for the next five years had to be used. These projections were obtained in a conversation with a specialist in the area.

committee activities was not included, since their participation was considered one of their normal tasks, and they did not have to be replaced when they were carrying out their duties as committee members (in contrast, the workers on the committee had to be replaced by supernumeraries).[12]

Concerning the automatic pallet distributor, the costs include the price of the machine, its maintenance, the cost of training workers to use it, and the cost of the extra time required to operate it. Indeed, the machine has to be filled periodically with "perfect" pallets that have not deteriorated, so that extra time has to be devoted to the selection of the good pallets and the filling of the machine. The foreman responsible for the machine estimates that this extra time is equivalent to 0.4 worker per year.
As stated above, as part of the S.A.Q.'s normal equipment-replacement policy, two new pallet trucks were bought in 1990 and these include the features designed by the members of the committee. As the cost relevant to our analysis, we consider only the expenditures for these extra features. Similarly, for the trucks, we take into account only the cost of the new seats.

Concerning the issue of stuck boxes, we considered the time involved to solve the problem when accounting for the time spent by the members of the committee on the various activities related to the program. Furthermore, magnet labels were purchased to identify the problematic piles.

For the wrapper, costs similar to those reported for the pallet distributor were taken into account. The wrapper does not require extra time from the workers, but it was found that, since the automatic wrapper is available, more Saranwrap is used by the workers to stabilize the piles on the pallet, since they wrap the piles more systematically. Finally, new gloves have to be bought every year.

5. Benefits of the Program

This section examines the benefits of the program. First, we will determine, through an econometric analysis, how many accidents have been prevented because of the program. Second, the savings associated with this reduction in accidents, in terms of direct and indirect costs, will be identified and evaluated. Third, the other benefits related to the program, such as increases in productivity, will be discussed.

[12] Similarly, the time spent in regular meetings by the members of the official joint safety committee when they took over the program after the strike was not included, given that, by law, the committee has to meet on a regular basis.

5.1 Accident Reduction

Inspired by the literature on the determination of workplace accident rates (e.g. Viscusi, 1986), we base our econometric analysis on the following model:

(1) ACCIDENTS = f(ERGONOMICS, CONTROL VARIABLES, ERROR TERM)

where ACCIDENTS refers to the incidence of workplace accidents (we will also investigate the risk of a back-related disorder), it is the phenomenon that we want to explain, or the dependent variable. Among the explanatory (or independent) variables, ERGONOMICS captures the existence of the participatory ergonomics program, and CONTROL VARIABLES refers to a set of factors other than the ergonomics program, such as age, that may influence the incidence of workplace accidents. All these variables will be described in detail below (their mean and standard deviation are provided in Table 3).

We have a set of data related to these variables for each C.D.Q. worker from 1987 to 1993. We are therefore using a panel data set covering about 90 workers (the labour force is very stable) for each year during that period.

As stated above, two dependent variables will be used. The first variable, ACCIDENTS, is the total number of accidents that a worker experienced during each year. Similarly, BACK is the number of back-related problems experienced during the year. Our analysis will be based on the Poisson regression model. Such a model is justified because of the clearly discrete nature of the dependent variable (it is composed of positive integers) characterized by the preponderance of zeroes and small values (see Dionne *et al.*, 1995, for an example of the Poisson model used with very similar data on the risk of airplane accidents).[13]

Concerning the independent variables, the first question is, How can we capture the presence of the ergonomics program? The most natural answer is to use a dummy variable equal to one for each observation during the years when the program was in place and zero otherwise. The program began in 1989; however, because of the strike, the first measures suggested by the committee were not implemented until 1991 (for instance, the automatic pallet distributor was bought during the summer of 1991). We thus suggest two initial measures: 1) ERGO1: equal to one for each observation

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[13]The equation of the Poisson model is: $Prob(Y_i = y_i) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i\,!}$ *où* $\lambda_i = \beta' \chi_i$

where y is the dependent variable, χ is a vector of independent variables and β, a vector of estimated coefficients.

during the period 1989-1993 inclusive and zero otherwise; and 2) ERGO2: equal to one for each observation during the period 1991-1993 inclusive and zero otherwise. Furthermore, given that the first measures were implemented in 1991, that these measures were still contributing to a safer workplace during the ensuing years, and that other measures were implemented later (for instance, the wrapper was bought in 1993), it may be reasonable to think that the effect of the program is gradually increasing over time, and, therefore, we suggest a third measure; ERGO3: equal to one in 1991, two in 1992, three in 1993, and zero otherwise.

Among the **control variables**, we first include the worker's AGE. It is expected that older workers may be more risk-averse and thus have fewer accidents. Similarly, we include the worker's years of EXPERIENCE at the S.A.Q., on the assumption that more experienced workers have developed habits to avoid accidents (for instance, see Lanoie 1992).

The third control variable is the number of OVERTIME hours per year. It is well documented that workers may become more tired during overtime, and this factor may increase the likelihood of an accident (e.g. Viscusi, 1979). We also include the hourly worker's WAGE, as a proxy of the opportunity cost of an accident for the worker; therefore, the higher the wage, the lower the probability of an accident should be (see, for instance, Johnson and Ondrich, 1990).

Furthermore, two dummy variables (STRIKE, AFTER-STRIKE) are introduced to capture the fact that workers probably experienced fewer accidents during the year the strike occurred,[14] and that they were bitter, dissatisfied and "rusty" in the year following the strike (see Table 1, there seems to be an abnormal increase in the accident rate in the year following the strike). In the same vein and on an exploratory basis, two other variables are included to investigate the idea that dissatisfaction in the workplace may lead to more accidents: 1) the number of GRIEVANCES per worker per year; and 2) the number of days of ABSENTEEISM per year (for causes not related to workplace accidents).

In addition, a variable is introduced to capture the STATUS of the worker. The variable is equal to zero if the worker is permanent and to one if he is an RNT (regular non titular.[15] It is not clear what the expected sign of this variable is: on the one hand,

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[14]The strike occurred between October 1990 and March 1991, and, for our purposes, a year lasts from the end of June to the first of July of the following year.

[15]These workers are on a calling list. They are asked to work mainly when regular workers are absent for any reason, during holidays, and when the S.A.Q.'s activities peak (around Christmas).

RNT workers are likely to have more accidents because they are generally less experienced but, on the other hand, they work more sporadically, which reduces their likelihood of having an accident.

We also include a dummy variable for each department within the C.D.Q. (RECEIVING, SHIPPING and DELIVERY; preparation is default) to account for the fact that more handling takes place in the preparation and shipping departments than in the others, so that workers in those departments are more likely to have a workplace accident. It can also be useful to examine the impact of the ergonomics program across the different departments because the project targeted mainly two departments: preparation and delivering. Therefore, we introduce an interaction term between the ERGO variables and SERVICE, a dummy variable capturing whether a worker was working in either of these services.

The **results** of the regressions are presented in Table 4. In Panel A, three regressions are presented with the total number of accidents as the dependent variable. Each of the specifications includes a different definition of the variable capturing the impact of the ergonomics program (ERGO1, ERGO2 and ERGO3). Panel B is based on the same pattern except that the dependent variable is the number of back injuries. In general, the statistical performance of the models is good, and the use of the Poisson model seems warranted.[16]

Our first interest concerns these variables related to the ergonomics program. Essentially, the program does not seem to have a significant impact on the total number of accidents, but it affects back-related injuries. Indeed, the only ERGO variable that is significant with the expected negative sign is ERGO3 in Panel B. These results are not surprising per se. The program was targeted toward back-related injuries, and it is plausible that its impact was cumulative over time (which is the implicit assumption in the definition of ERGO3).

From this result, we can deduce the number of back-related injuries that have been prevented as a result of the program.[17] These are reported in Table 5. It is important

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[16] In particular, in the Poisson model, it is implicitly assumed that the mean of the dependent variable is equal to its variance. According to Dionne *et al*. (1995), this assumption can be tested with an equidispersion test. If this test is applied to our data, it is not possible to reject the null hypothesis of a Poisson model.

[17] To do so, we use the estimated coefficients and the mean of the independent variables to compute the predicted average probability of a back-related injury, and we evaluate how this probability is affected when the ERGO variable goes from 0 to 1 in 1991, from 1 to 2 in 1992, and from 2 to 3 in 1993. In doing this calculation, we take into account that the ERGO variable also appears in the interraction term SERVICE ERGO.

to note that this table reports the additional number of back-related accidents prevented over time and the total number of accidents prevented which is cumulative (i.e. if the program prevented six accidents in 1991 and five more in 1992, the total number of accidents prevented in 1992 is 11, in comparison to the situation without the program).

When we consider our second scenario, which includes the predicted costs and benefits for the next five years, it does not seem reasonable to assume that the rate of back-related injuries will continue to decline at the pace experienced between 1991 and 1993. This would imply that back-related problem would eventually disappear, which seems unrealistic. We will instead assume that the total reduction in back-related injuries reached in 1993 will persist during the five following years.[18] This assumption seems acceptable, given that no major measure related to the program was implemented after 1993.

Concerning the control variables included in the regression (our discussion is based on specification 3, Panel B, Table 4), it is noteworthy that the likelihood of a back-related injury is reduced by the number of years of EXPERIENCE and the fact that the worker has a non-permanent STATUS. Still, as expected, the year AFTER the STRIKE is associated with a greater likelihood of back-related injuries, such as the total number of days of ABSENTEEISM. Interestingly, this is the first result showing that a measure of dissatisfaction at work is related to a greater incidence of back injuries.

5.2 Savings in Terms of Direct and Indirect Costs

As already stated, an accident gives rise to direct and indirect costs; therefore, preventing accidents means that these costs are avoided. We first wanted to evaluate what are the **indirect costs** of an accident at the C.D.Q. No information had been collected on this matter, so we had to design our own questionnaire (based on Brody *et al.*, 1990 and Bertrand, 1991) to obtain the required data on all the indirect expenses related to an accident.[19]

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[18] This means we assume that 15 accidents are prevented in each of the following years, compared with the situation without the ergonomics program.

[19] These include items such as time lost by the supervisor or fellow workers during the accident, material losses, loss of productivity, administrative costs, etc. For more details, see Tavenas (1995).

The questionnaire was ready in April 1994, and we collected information on the first 17 accidents to occur after that date. As Table 1 shows, 58 accidents were recorded in 1993 so that a sample of 17 is fairly representative. Like Pérusse (1993), we included accidents with and without time lost. One shortcoming of our approach is that we are collecting information about accidents that are occurring after the ergonomics program was implemented, and it is not clear that the accidents prevented are of the same nature as those that are still occurring.

Our compilation showed that the average indirect cost of an accident was $1,887.83 (1994 Can. $), for an average of 7.4 days lost per accident and, therefore, $255.11 per day lost. Of the 17 accidents that were documented, seven were back-related problems for which the indirect cost was on average $2,196.29, for an average of 11 days lost per accident and, therefore, $199.66 per day lost. Since our statistical results show that the ergonomics program has been effective in preventing back-related accidents, we will consider the indirect cost compiled for this category. In fact, given that, in our global sample, the average number of days lost for a back-related injury is 16.5 (see Table 1), we use as our figure for the average indirect cost of an accident prevented: 16.5 X $199.66 = $3,294.39. This number is in 1994 dollars and has to be deflated to obtain the appropriate savings in 1991-92-93.[20]

Each accident also imposes a **direct cost** on the firm in terms of wage replacement and medical costs. Each firm pays an insurance premium to Quebec's workers compensation board which, in turn, compensates the accident victims for their wage loss and assumes the medical costs. For firms that are experience-rated, these premia are adjusted to reflect their accident records. It is through this mechanism that the direct costs of an accident are reflected on the firm's balance sheet, and that accidents prevented may mean a lower bill to the compensation board.

There is an experience-rating system in Quebec which, like most experience-rating systems in North America, puts more weight on the firm's own accident experience, in the calculation of the insurance premium, as the size of the firm increases. Given that the S.A.Q. is a very large firm (sales of $1 billion in 1994), its personalised premia almost entirely reflect its own experience. Furthermore, the experience rating is done on a retroactive basis, which implies that a reduction in the number of accidents in a given year will be reflected in the firm's insurance bill three years later. This retroactive mechanism is put in place so that all the costs related to an accident occurring in a given year are known before a firm can be rewarded or punished because of its accident record.

A financial analyst with the S.A.Q. provided us with the latest calculation available in 1994 concerning the accidents that occurred in 1991. He was able to show that a

[20]The Consumer Price Index was used as the deflator.

reduction of one day of compensation in 1991 results in a saving of $221.31 (1994 Can. $) in the insurance bill.[21] Again, since a back injury in our sample involves an average of 16.5 days lost, the total direct cost of an accident is $3,651.62. It is noteworthy that our ratio of indirect cost over direct cost is 0.87 for back-related injuries and 1.11 for all accidents, which is similar to what was found by Grimaldi and Simonds (1984), Brody *et al.* (1990) and Bertrand (1991).

We use the $3,651.62 figure and deflate it to find out how much money the ergonomics program has saved in terms of direct costs.[22] Table 6 provides the figures for the total sums saved in terms of direct and indirect costs, and according to both of our scenarios.

5.3 Other Benefits

Of course, accident reduction is the main benefit of the ergonomics program, but other benefits have potentially been generated. These benefits may be classified in three categories: increase in productivity, reduction in material losses and improvement of the industrial relations environment.

The automatic pallet distributor has potentially increased **productivity** because it allows worker to install pallets on their pallet trucks faster. This impact was very hard to measure and possibly fairly small, since the normal task of the workers using the new device has not been increased. Furthermore, as already stated, the pallets to be put in the distributor now have to be selected more carefully, which implies some extra time, which was included in the costs of the program. In the same vein, the wrapper machine makes the wrapping operation quicker, but this effect is potentially offset by the fact that, with the machine, workers wrap piles (to be put in trucks) more systematically than they used to. The solution of the stuck boxes could also potentially improve productivity, given that workers spend less time unsticking them, but again this is difficult to measure.

Similarly, resolving that problem has potentially reduced **material losses** because stuck boxes were often torn during handling. Moreover, more systematic wrapping of piles has reduced the number of bottles broken in trucks. The S.A.Q. has data on the number of bottles broken per year, but unfortunately does not record the cause of

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[21] At this stage, we cannot distinguish between back injuries and other types of injuries.

[22] We implicitly assume that the savings related to 1991 can be applied to the following years.

breakage. Examining these general numbers (see Tavenas, 1995), we see that there is a downward trend in the total number of broken bottles starting in 1991, but there is no way to be sure that it is due to the ergonomics program. In the same vein, the automatic distributor has potentially reduced the number of broken pallets. Again, the S.A.Q.'s statistics on that matter do not allow us to determine whether the reduction in the number of broken pallets (indeed observable after 1991) is due to the program.

Finally, it seems clear that the program has improved the **employees' working conditions**, and potentially their satisfaction, by eliminating painful tasks (unsticking boxes, wrapping etc.). According to some of the workers and foremen whom we interviewed, the measures implemented during the program have most likely enhanced the working potential of the aging labour force at the C.D.Q. Furthermore, the participatory ergonomics program has put in place a new way for the workers and management to carry on a dialogue, which has improved the industrial relations environment. In particular, some of the individuals interviewed said that the recent decrease in the number of grievances at the C.D.Q. can be attributed to the program. These elements are, of course, very difficult to measure, but they are better documented in the work of our co-researchers, who investigated the socio-dynamic aspects of the program.

6. Cost-benefit Analysis

The final step of our analysis is to compute the net present value of the ergonomics program. As discussed earlier, we consider two scenarios: 1) one with the costs and benefits as they have been recorded until now (July 1994); and 2) one where we assume that the program will have an impact during the five subsequent years. A crucial element at this stage is the choice of the rate used to actualize the flows of costs and benefits. Given that the analysis is made from the S.A.Q.'s point of view, its own actualization rate was selected, and, given that the decision related to the project was made at the beginning of 1989, we chose the actualization rate prevailing at that time, i.e. 11.5%. This rate accounts for expected inflation so that we were warranted in using figures in current dollars (and figures that account for predicted inflation in our second scenario, see Anderson and Settle, 1991).

From the numbers computed in Tables 2 and 6, it appears that the net present value of the project in our first scenario is slightly negative (- $7,982.64), but strongly positive ($187,700.79) in our second scenario. It is thus fair to conclude that the program has been **profitable** for the enterprise. Examining Tables 2 and 6, we see that the net present value becomes positive immediately in the first year added in the second scenario, and that the positive value increases with the number of years in which we assume that the program will have an impact. Furthermore, from Table 7, it is noteworthy that our main conclusion is not altered when we consider three other actualization rates (5%, 10% and 15%).

7. Discussion and Concluding Remarks

This paper has provided a cost-benefit analysis of a participatory ergonomics program conducted at the beginning of the 1990s to reduce back-related disorders among packers at a warehouse of the Société des Alcools du Québec in Quebec City. After an evaluation of the costs of the program, we have presented a rigorous econometric analysis to assess how many accidents have been prevented because of the program so as to compute the savings in terms of direct and indirects costs avoided in relation to such accident reduction. We showed that the program has been profitable for the firm.

As emphasized in Section 5, we have the impression that most of the costs of the program were taken into account, but it was not possible to account for all its benefits; we had to focus on the benefits related to accident reduction. This, of course, reinforces our impression that the program has been profitable.
Furthermore, in our analysis, we adopted the point of view of the firm, but it would also be relevant to ask whether the program has been profitable for society as a whole. This would involve, in addition to the costs and benefits already identified, evaluating the worker morbidity and suffering avoided by the reduction in accidents.[23] This is a difficult task. Viscusi (1993), in a literature survey, shows that economists who have tackled this question obtained a morbidity value per accident in the $25,000 to $50,000 range (1990 U.S. dollars). It is thus clear that taking this aspect into account would lead us to conclude that the program has been profitable for society as a whole.

Of course, one cannot generalize from our study that prevention programs introduced to enhance safety in the workplace are necessarily profitable for the firms that adopt them. Still, it is noteworthy that all studies (see Section 2) that examined the costs and benefits of prevention programs reached the same conclusion. Ours is the first to show that prevention mechanisms involving worker participation are a promising tool to reduce the costs and suffering related to workplace accidents.

[23] Other expenses related to the program have been incurred by the Institut de recherche en santé et sécurité du travail (e.g. the wage of the person who provided the training), but they were negligible. Taking them into account would not alter our conclusions.

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Table 1

Workplace Accidents at C.D.Q.

	1993	**1992**	**1991**	**1990**[1]	**1989**	**1988**	**1987**	**TOTAL**
Accidents:								
With Loss of Time	24	13	35	22	16	21	20	151
Without Loss of Time	30	45	33	30	29	24	30	221
Recurrences[2]	4	9	5	7	9	3	6	43
Total	**58**	**67**	**73**	**59**	**54**	**48**	**56**	415
Workdays Lost Due to Back-related Injuries[3]:								
Back-Related Injuries	290	202	563	540	182	240	262	2,279
Other Accidents	129	406	628	78	522	112	122	1,997
Total	**419**	**608**	**1,191**	**618**	**704**	**352**	**384**	**4,276**
Back-related Injuries:								
Number	13	14	34	24	16	15	21	137
Percentage	22.4%	20.9%	46.6%	40.7%	29.6%	31.3%	37.5%	33.0%
Number of Workers in the sample	82	90	90	90	88	85	80	605
Accidents/ 100 Workers	71	74	81	66	61	57	70	
Back-Related Injuries/ 100 Workers	16	16	38	27	18	18	26	

Notes:

1) C.D.Q. workers were on strike from October 1990 to March 1991.

2) Recurrences indicated are either with or without workdays losses.

3) Workdays lost after June 30 are reported the following year.

Table 2
Costs of the Intervention in Current and 1989 Dollars

		Current Dollars	Year	Scenario 1 1989 Dollars	Scenario 2 1989 Dollars
Training	Supranumeraries wages	2,184.59	1989	**2,184.59**	**2,184.59**
Time devoted to the activities related to the intervention	Supranumeraries wages	62,726.16	1989	62,726.16	62,726.16
	Supranumeraries wages	15,778.13	1990	14,150.79	14,150.79
	Total			**76,876.95**	**76,876.95**
Automatic Palett Distributor	Purchase	35,173.20	1991	28,291.90	28,291.90
	Training	227.20	1991	182.75	182.75
	Maintenance	85.00	1993	54.99	54.99
	Extra labour costs	19,600.13	1991	15,768.41	15,768.41
	Extra labour costs	20,469.10	1992	14,768.47	14,768.47
	Extra labour costs	21,084.62	1993	13,638.18	13,638.18
	Extra labour costs	21,989.80	1994		12,755.10
	Extra labour costs	22,931.18	1995		11,930.89
	Extra labour costs	23,920.85	1996		11,162.32
	Extra labour costs	24,946.71	1997		10,442.32
	Extra labour costs	26,020.86	1998		9,767.59
	Total			**72,704.70**	**128,762.92**
Palett Truck	Purchase	1,049.50	1990	941.26	**941.26**
Stuck Boxes	Magnetic Labels	500.00	1991	402.18	**402.18**
Trucks	Ergonomic Truck Seats	400.00	1990	358.74	**358.74**
Wrapper	Purchase	11,345.00	1992	8,184.27	8,184.27
	Installation	300.00	1993	194.10	194.10
	Maintenance	119.22	1993	184.27	184.27
	Training	52.32	1993	33.85	33.85
	Plastic wrap	2,209.17	1993	1,429.32	1,429.32
	Plastic wrap	2,414.82	1994		1,401.20
	Plastic wrap	2,451.04	1995		1,275.60
	Plastic wrap	2,495.16	1996		1,164.60
	Plastic wrap	2,545.06	1997		1,065.37
	Plastic wrap	2,595.97	1998		974.61
	Total			**10,025.81**	**15,907.19**

Gloves	Prototype	60.00	1991	48.26	48.26
	Purchase	1,056.00	1992	761.80	761.80
	Purchase	348.00	1993	225.15	225.15
	Purchase	348.70	1994		202.33
	Purchase	353.93	1995		184.20
	Purchase	360.30	1996		168.17
	Purchase	367.50	1997		153.84
	Purchase	374.85	1998		140.73
	Total			**1,035.21**	**1,884.48**
Total Costs				**164,529.44**	**227,318.31**

Table 3
List of Variables and Sample Descriptive Statistics

Variable	**Definition**	**Mean**	**Standard Deviation**
Workplace Accidents	Workplace accidents and recurrences per worker per year	0.6882	1.011
Back-related Injuries	Back-related injuries per worker per year	0.2239	0.5717
Age	Age of worker	37.86	9.56
Experience	Years of experience cumulated by the worker at the S.A.Q.	11.99	7.37
Wage	Hourly wage according to the collective agreement	15.34	1.727
Grievances	Number of grievances per worker per year	0.1542	0.5003
Status	Worker's status; regular=0, RNT=1	0.199	0.3996
Strike	Six month strike in 1990 (0, 1=1990)	0.1493	0.3566
Year after the strike	Year following the 1990 strike	0.1493	0.3566
Absenteism	Hours of absenteism per worker per year	78.29	75.35
Overtime	Overtime hours per worker per year	60.17	78.35
Preparation	Portion of the year worked at the preparation service	0.3522	0.4529
Receiving	Portion of the year worked at the reception service	0.1572	0.3507

Expedition	Portion of the year worked at the expedition service	0.496E-01	0.205
Shipping	Portion of the year worked at the shipping service	0.1461	0.341
Ergo1	Ergonomics (0,1=1989 à 1993)	0.7297	0.4445
Ergo2	Ergonomics (0,1=1991 à 1993)	0.4345	4961
Ergo3	Ergonomics (0,1=1991, 2=1992,...)	0.8557	1.114
Service	Portion of the year worked at the preparation or shipping service	0.4983	0.4754
Service * Ergo1	Multiplication of both variables	0.3632	0.4651
Service * Ergo2	Multiplication of both variables	0.2236	0.4052
Service * Ergo3	Multiplication of both variables	0.4485	0.903

Table 4

Results of the Regression Analysis (t-ratio)

	Panel A: Accident			**Panel B: Back-related injuries**		
	Ergo 1	**Ergo 2**	**Ergo 3**	**Ergo 1**	**Ergo 2**	**Ergo 3**
Intercept	-0.0910 (-0.148)	-1.1706 (1.035)	0.5522 (0.486)	-0.1765 (-0.137)	-1.7816 (-0.862)	1.8276 (-0.886)
Age	-0.0117 (-1.475)	-0.0109 (-1.372)	-0.0104 (-1.302)	-0.0257** (-1.766)	-0.0243** (-1.659)	-0.0233 (-1.602)
Experience	-0.0252** (-1.814)	-0.0250** (-1.760)	-0.0262** (-1.865)	-0.0756* (-2.473)	-0.0835* (-2.699)	-0.0832* (-2.720)
Wage	0.0225 (1.035)	0.0763 (-0.950)	-0.0318 (-0.401)	0.0354 (0.396)	0.1479 (1.004)	0.1450 (0.996)

Grievances	-0.0608 (-0.571)	-0.0388 (-0.364)	-0.0489 (-0.458)	-0.3283 (-1.359)	-0.3085 (-1.320)	-0.3089 (-1.314)
Status	-0.7161* (-3.606)	-0.6989* (-3.521)	-0.6977* (-3.522)	-0.7084* (-2.083)	-0.6448 (-1.852)	-0.6297** (-1.812)
Strike	-0.0283 (-0.181)	0.2267 (1.136)	0.1402 (0.723)	0.4444** (1.668)	0.1311 (0.392)	0.1403 (0.426)
Year after strike	0.1322 (-0.939)	-0.0062 (-0.036)	0.2587 (1.659)	0.6838* (2.908)	0.8827* (2.929)	0.5657* (2.187)
Absenteism	0.0021* (-3.16)	0.0019* (2.914)	0.0019* (-2.905)	0.0027* (2.376)	0.0027* (2.416)	0.0027* (2.434)
Overtime hours	0.0009 (-0.998)	0.0012 (1.318)	0.0012 (1.304)	-0.0024 (-1.371)	-0.0027 (-1.512)	-0.0026 (-1.434)
Receiving	-0.1953 (-0.937)	-0.0546 (-0.302)	-0.0232 (-0.131)	0.0171 (0.047)	0.1610 (0.519)	0.2306 (0.755)
Shipping	-0.9069* (-2.275)	-0.7151** (-1.880)	-0.7008** (-1.856)	-0.1111 (-0.182)	-0.0322 (-0.056)	0.0453 (0.080)
Delivery	-0.2143 (-1.038)	-0.1924 (-0.937)	-0.2088 (-1.011)	0.2137 (0.559)	0.1564 (0.408)	0.1468 (0.381)
Status	0.1765 (-0.598)	0.1929 (0.674)	0.3244 (1.091)	-0.7270 (-1.359)	-0.4697 (-0.888)	-0.3354 (-0.612)
Service * Ergo	0.0309 (-0.150)	0.3816** (1.878)	0.2281* (2.365)	0.0293 (0.083)	0.4378 (1.241)	0.3715** (1.878)
Ergonomics	0.0848 (-0.400)	0.2907 (0.832)	-0.0101 (-0.071)	-0.1844 (-0.498)	-0.8293 (-1.353)	-0.4526** (-1.670)
Likelihood Function	-687.711 0	-684.104 6	-683.682 2	-343.565 6	-342.513 3	-341.550 1
Likelihood Ratio	44.27	51.48	52.33	43.70	45.80	47.73

(*) Significant at a 5% level.

(**) Significant at a 10% level.

N = 603 observations.

Table 5

Number of Back-Related Injuries Prevented at the C.D.Q.

Value of ERGO3	Average frequency	Absolute number of back-related injuries	Prevented back-related injuries	Total number of prevented back-related injuries
ERGO3 = 0	0.3092	26.63	Not relevant	Not relevant
ERGO3 = 1	0.2366	20.38	6	6
ERGO3 = 2	0.1811	15.59	5	11
ERGO3 = 3	0.1386	11.93	4	15

Table 6
Present Value of Benefits in Terms of Indirect Costs Avoided Due to Back-Related Injuries Prevention

Year	Value in current dollars	Present value (1989 dollars) Scenario 1	Present value (1989 dollars) Scenario 2
1991	19,091.70	15,356.90	15,356.90
1992	35,526.48	25,628.68	25,628.68
1993	49,317.15	31,908.09	31,908.09
1994	49,415.85		28,673.47
1995	50,157.15		26,103.12
1996	51,059.85		23,831.90
1997	52,081.05		21,801.27
1998	53,122.80		19,943.99
	TOTAL:	72,893.67	193,247.42

Present Value of Benefits in Terms of Direct Costs Avoided Due to Back-Related Injuries Prevention

Year	Value in current dollars	Present value (1989 dollars) Scenario 1	Present value (1989 dollars) Scenario 2
1991	21,909.72	17,623.65	17,623.65
1992	40,770.29	29,411.55	29,411.55
1993	56,596.65	36,617.92	36,617.92
1994	56,709.90		32,905.83
1995	57,560.55		29,956.05
1996	58,596.60		27,349.64
1997	59,768.55		25,019.28
1998	60,963.90		22,887.78
	TOTAL:	83,653.12	221,771.70

Table 7

Sensitivity Analysis
Scenario 1

	5%	10%	15%
Σ Benefits	190,233.90	163,548.90	141,725.90
Σ Costs	153,614.10	136,036.50	117,058.40
Net Present Value	36,619.00	27,512.40	24,667.50

Sensitivity Analysis
Scenario 2

	5%	10%	15%
Σ Benefits	580,941.76	447,032.73	351,274.63
Σ Costs	275,171.17	236,631.29	208,198.39
Net Present Value	305,770.59	210,401.44	143,076.24

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