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Série Scientifique
Scientific Series

95s-45

Costs and Benefits of Preventing Workplace Accidents : Going from a Mechanical to a Manual Handling System

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Montréal
novembre 1995

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ISSN 1198-8177

Costs and Benefits of Preventing Workplace Accidents : Going from a Mechanical to a Manual Handling System*

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Résumé / Abstract

Les auteurs de cet article ont effectué l'analyse coûts-avantages du passage d'un système de manutention mécanisé à un système manuel mis en oeuvre en 1990 dans un entrepôt de la Société des Alcools du Québec situé à Montréal. Après avoir estimé les coûts du programme, ils ont conduit une analyse économétrique rigoureuse pour déterminer le nombre d'accidents évités grâce à ce changement. 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 changement a été rentable pour l'entreprise.

This paper provides a cost-benefit analysis of the passage from a mechanical to a manual handling system that took place at the beginning of the 1990s at a warehouse of the Société des Alcools du Québec in Montreal. In particular, this change was aimed at reducing workplace accidents among packers. After evaluating the costs of the program, we present a rigorous econometric analysis to assess how many accidents have been prevented by the change so as to compute the direct and indirects costs avoided as a result of such accident reduction. We show that the "demechanization" of the handling system has indeed been profitable for the firm.

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* Financial support from the Fonds FCAR and the Institut de recherche en santé et sécurité du travail (IRSST) is gratefully acknowledge. Inthe course of this research, we benefited from useful comments by Bernard Brody, Jean-François Chanlat, Marie-Claire Carpentier-Roy, Marcel Dagenais, Gilles Gauthier, Alain Marchand, Louis Patry and Marcel Simard, and we wish to thank them all. We are also grateful to Michel Bonenfant, Jean-Jacques Fleury, Daniel Lalonde and Donald Villeneuve of the Société des Alcools du Québec (S.A.Q.) for very helpful discussions and for assistance in building our data base. Finally, we thank Sophie Tavenas and Alexandre Le Leyzour for expert technical assistance.

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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].

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 activities to prevent job-related accidents. And firms will adopt these activities 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 activity adopted by a Canadian firm[4]: the passage from a mechanical to a manual handling system that took place at the beginning of the 1990s at a warehouse of the Société des Alcools du Québec (S.A.Q.) in Montreal. In particular, this change was aimed at reducing workplace accidents among packers[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 aimed at showing that, paradoxically in our modern work environment, "demechanization" can be profitable. It is also innovative in presenting a rigorous econometric analysis to evaluate the change's impact on the accident rate, while previous studies (except a companion paper by Lanoie and Tavenas, 1995) 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 context in which the passage from a mechanical to a manual system took place. 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 change 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 "demechanization". Section 6 provides a comparison of the intervention's costs and benefits, in which it is shown that it has been profitable for the firm. Finally, Section 7 concludes.

2. A Brief Survey of the Literature

We surveyed five studies that have performed a cost-benefit analysis of a prevention program aimed at job-related accidents. First, Harms-Ringdhal (1990) provides a

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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 accident-prevention activities in this warehouse. Other aspects of the program were studied by an ergonomist and two specialists in socio-dynamic aspects of working conditions.

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 of 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.

Fourth, 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.

Lastly, in a companion paper, Lanoie and Tavenas (1995) provide a cost-benefit analysis of a paticipatory ergonomics program conducted at the beginning of the 1990s to reduce back-related disorders among packers at another warehouse of the Société des Alcools du Québec in Quebec City. For the first time, the paper presents a rigorous econometric analysis to assess how many accidents have been prevented by the program so as to compute the direct and indirect costs avoided as a result of such accident reduction. They show that the program has been profitable.

This brief summary shows that no "demechanization" process has ever 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, except in our companion paper. 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 Intervention & Context

The Société des Alcools du Québec (S.A.Q.) is the only authorized distributor of wine and liquor in the province of Québec, Canada. Its 3400 different products come from more than 50 countries and are sold through its 350 branches. 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 done at these warehouses consists mainly in gathering a variety of different products required by the branches. Prior to 1990, the C.D.M. used to rely on the mechanical assistance of conveyors to help workers gathering products to be shipped to branches and clients. At the end of the 80's, the system has proved to be inefficient on many aspects. It has become a source of several work annoyances such as noise, accident risk (see Table 1; in particular, nets were installed to prevent boxes to fall on workers!) and boring repetitive tasks. In addition to these factors, the system was frequently stopped by mechanical breakdowns and mistakes in orders were frequent and hard to solve.

In the fall of 1990, during a strike that lasted from October 1990 to March 1991, a new preparation of orders system was implemented. A transition plan was activated to use space efficiently during the dismantlement of the mechanical system. The new system relies mostly on warehouse workers who go through the alleys with forklift

[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.

trucks and pallet trucks (equipped with wooden pallets) to pick up the required products by branches on shelves. The implementation of this system necessited the SAQ to buy new equipments for its Montreal warehouse[7]. The shelving system was completely renewed, in order to allow workers to get boxes from the shelve spaces to their pallet truck. Several modifications were made to the building including the creation of a battery charge and storage room required by the presence of more electric powered vehicles in the warehouse.

The S.A.Q. also bought an automatic pallet distributor. The new system increased the use of wooden pallets by preparation of orders workers. Without this device, workers would have had to take heavy wooden pallets from the top of a high stack to install them on their pallet truck. The effort to make that kind of operation is thus significantly reduced. The computer system was also adapted to the new system by S.A.Q. programmers to dispatch orders. Lastly, training was provided to workers by the S.A.Q. health service personnel to teach workers how to manipulate boxes in a way that prevents back-related injuries. Note finally that the warehouse has four main departments: receiving, preparation of orders, shipping and delivery.

[7] The Quebec warehouse never had a mechanical system.

4. Costs of the Intervention

The next two sections offer a description of costs and benefits generated by the implementation of the new system. Costs and benefits are reported in Table 2 and are computed up to the latest period the data was available (end of June 1994)[8].

The purchases of equipment include the shelving system, pallet trucks, forklift trucks and the automatic pallet distributor. The numbers provided in the Table include installation and delivery fees. Costs related to engineering are honoraries for tailor-made design of parts and equipements. Modifications to the building are mainly related to the installation of a battery storage room and the reallocation of space to allow pallet trucks to circulate all over the shelving area.

Furthermore, as will discussed in more details below, the "demechanization" of the warehouse has paradoxically involved 19 job cuts, especially among mechanics, electricians and warehouse janitors. Ten of them decided to enter into an early retirement plan offered under specific conditions by the S.A.Q. (a minimum seniority as a S.A.Q. worker was required) in 1992. Between 1990 and 1992, they were affected to new tasks within the warehouse. For the purpose of our study, compensations to these workers were accounted as a cost of the implementation since this early retirement plan is not offered on a regular basis.

5. Benefits of the Intervention

Benefits that are credited to the new system come from three main sources: labour costs savings, savings on indirect and direct costs by preventing accidents and decreases in material losses[9].

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[8] For our purposes, following the convention prevailing at the S.A.Q., a year lasts from the end of June to the first of July of the next year.

[9] One could also think about savings in energy used. However, the new system involves more lighting and use of more electricity for the new palett trucks. Furthermore, change in electricity consumption could be attributable to changes in climatic conditions or in the demand for the S.A.Q. products. Altogether, it was thus difficult to identify correctly energy savings, if any, related to the new system.

5.1. Labour Costs Savings

The savings are calculated using the currrent wage of the workers whose jobs were cut. These savings are relatively small in 1990 because of the strike and because the affected workers left gradually after the introduction of the new system. Nine workers retired without pre-retirement compensation or found a job elsewhere. It is noteworthy that, although our analysis is conducted on the period 1990-93, these economies are there for good.

5.2 Accident Reduction

To estimate the accident reduction attributable to the new system, the following econometric specification inspired from Viscusi (1986) was used:

(1) *accidents= f (NEWSYSTEM, CONTROL VARIABLES, ERROR TERM)*

where the dependent variable, accidents, is the frequency of workplace accidents during a year[10]. Concerning explanatory variables, NEWSYSTEM captures the introduction of the new system and its effect on workplace accidents, while control variables, such as age and seniority, provide the model with specific information that can explain workers'behaviour in presence of risk of workplace accidents. The full definition of these variables accompanied by their respective mean and standard deviation are presented in Table 3.

Our data set features all these variables for each warehouse worker acting on a regular basis in preparation of orders, receiving, shipping and delivery services. In this unbalanced panel data set, about 350 workers are covered over 7 years (1987-1993 inclusively) to capture the impact of the introduction of the new sytem at the end of 1990.

An important issue is the creation of the variable capturing the introduction of the new system. Our variable is defined as NEWSYSTEM=1 for observations during year 1991, 2 for 1992 and 3 for 1993, 0 otherwise. This formulation seems reasonable given that the effect of the new system is likely to be gradually increasing over time[11].

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[10] A set of estimations was also performed with back-related injuries as the dependent variable. However, as will become clear, these regressions only presented a partial picture of the realized economies due to accident prevention.

[11] Another possibility was investigated; i.e., NEWSYSTEM2=1 for observations during years 1991-1993, 0 otherwise. However, we find the pattern depicted by

For instance, the change was followed in 1992 and 1993 by constant improvements such as increased experience by workers and new procedures to limit the number of orders prepared by workers.

Among the other 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, 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, 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, in 1992, the C.D.M. has adopted new production requirements (quotas) for workers based on a time-and-movement study. According to managers and workers interviewed, this measure has enhanced productivity, but also pressure on workers and some dissatisfaction, leading to more accidents. We thus introduce a variable TIME-AND-MOVEMENT equal to 1 for observations in 1992, and 0 otherwise.

A variable is also included 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

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NEWSYSTEM more appropriate and, indeed, the results associated with the use of NEWSYSTEM2 (available upon request) were not realistic given the observed trend of workplace accidents.

titular)[12]. It is not clear what the expected sign of this variable is: on the one hand, 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.

Furthermore, we noticed that most of the accident victims already had an accident in the preceding year. Since we had data on accidents in 1986 and workers' assignment, we include, on an exploratory basis, a dummy variable PRECEDING YEAR (=1 if a worker had an accident the preceding year, 0 otherwise). This reflects the possibility that, for a number of reasons (risk aversion, carelessness etc.), some workers are more likely than others to experience an accident.

We also include a variable indicating the part of the year spent working in each department within the warehouse (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. Furthermore, again on an exploratory basis, we include a variable to capture the fact that accident reductions due to the new system are more likely for preparation workers than for others. This is the interraction term defined as NEWSYSTEM*SERVICE where SERVICE is the portion of the year worked at the preparation of orders service.

As a first step, we used the Poisson regression model due to the nature of our dependent variable (positive integers, many zero values). However, the Poisson regression model assumes implicitly that the mean of predicted values is equal to their variance. Estimations of the accident equation provided good results, but overdispersion tests[13] led us to reject the Poisson regression model. Another series of estimations was performed using the negative binomial regression model, a specific form of the Poisson regression model that allows us to relax the mean-variance equality assumption. Support for using this model is provided by the significance (at the 99 % level) and the positive sign of variance parameter alpha (see Table 4)[14]. Table 4 presents three specifications of equation (1): i) a full specification, ii) a

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[12] 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).

[13] See Dionne *et al.* for details.

[14] See LIMDEP manual for details on the variance specification used in our estimations.

specification without the PRECEDING YEAR variable, and iii) a specification without the interaction term. Results are very robust across specifications.

For the purpose of our cost-benefit analysis, the value and significance of the NEWSYSTEM parameter is determinant. This parameter ranges from -0.24995 to -0.27490 across specification, which seems in line with the actual accident reduction observable following the introduction of the new system. Results of the calculations that were performed to estimate the actual number of prevented accidents by the new system are shown in Table 5 (these numbers are based on the results of the third specification)[15]. Prevented accidents shown in 1991 to 1993 are should be considered on a marginal basis. It means that these prevented accidents are added to those of preceding years (i.e., if the change prevented 26 accidents in 1991 and 12 more in 1992, the total number of accident prevented in 1992 is 38, in comparison to the situation without the change).

Concerning the other control variables included in the regression, it is noteworthy that the likelihood of an accident 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 an accident, such as the number of GRIEVANCES. Interestingly, these show that measures of dissatisfaction at work are related to a greater incidence of accidents. Maybe in line with this, we observe that the occurrence of an accident in the preceding year increases significantly the probability of an accident in the present year.

[15] To do so, we use the estimated coefficients and the mean of the independent variables to compute the predicted average probability of an accident, and we evaluate how this probability is affected when the NEWSYSTEM variable goes from 0 to 1 in 1991, from 1 to 2 in 1992, and from 2 to 3 in 1993.

5.3 Savings in Terms of Direct and Indirect Costs

With the number of prevented accidents in hand, we had to establish the indirect and direct costs that are supported by the S.A.Q. in case of workplace accidents. We first wanted to evaluate the indirect costs which include: victim's wage for the balance of the day, loss of productivity, mechanical repairs,etc. To estimate these costs, we used 1994 data from the Québec City S.A.Q. warehouse found in Lanoie and Tavenas (1995). To collect this data, a questionnaire was built based on Brody et al. (1990) and Bertrand (1991). The sample used features 17 accidents (with or without loss of time) out of 58 that happened in the Québec City warehouse that year.

From this data, we deduced an average indirect cost by accident of $ 1887.83 (1994 cdn $) for an average of 7.4 days lost. In our data base, the average number of days lost due to workplace accidents is 13.21. The average indirect cost for one day lost is thus $ 255.11. Results regarding the total indirect costs avoided are reported in Table 2.

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 1995 concerning the accidents that occurred in 1992 (and also the calculation related to 1991). He was able to show that a reduction of one day of compensation in 1991 results in a saving of $221.31 (1994 cdn $) in the insurance bill and $ 149.28 (1995 cdn $) for days lost in 1992 and 1993. Results showing the overall direct costs avoided because of the change are shown in Table 2.

5.4 Other Benefits

Other benefits were also generated by the new system according to managers and workers. First, the new system helped reduce bottle breaks. Under the former system, boxes used to break after a fall from conveyors. Since these conveyors are not used anymore and since workers have more control over the manipulation of boxes, annual costs relative to breaks decreased by about 66 % in constant dollars.

Several unquantifiable benefits were also generated by the new system. Since 1990, the general working environment has improved in the warehouse. Apparently, before 1990, warehouse workers were not motivated to come to work. The noise level was very high, most tasks were repetitive and annoying, drug use and alcoholism were observed at an abnormally high level and absenteeism was frequent[16]. The new system has also allowed the SAQ to reduce by approximately 50 % the number of mistakes in orders shipped to branches (workers are now informed of their performance with this respect), and to eliminate delays in the shipping to branches, which was absolutely impossible before 1990. Again, such benefits are very difficult to quantify.

6. Cost-Benefit Analysis

The final step of our analysis is to compute the net present value of the "demechanization" of the system. 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 change was made in 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 (see Anderson and Settle, 1991).

From the numbers computed in Table 2, it appears that the net present value of the project is unquestionably positive ($ 936 998.97) It is thus fair to conclude that the change has been highly **profitable** for the enterprise. Given that the costs of this change were concentrated at the moment of the change and that benefits continue to occur, it is reasonable to believe that our conclusion would be reinforced if we have

[16] These elements are better documented in the work of our co-researchers that investigated the socio-dynamic aspects of working at the C.D.M.

made any attempt to forecast the net benefits of the change in the years after 1993. Furthermore, from Table 6, it is noteworthy that our main conclusion is not altered when we consider three other actualization rates (5%, 10% and 15%).

7. Concluding Remarks

This paper has provided a cost-benefit of the passage from a mechanical to a manual handling system that took place at the beginning of the 1990s at a warehouse of the Société des Alcools du Québec in Montreal. In particular, this change was aimed at reducing workplace accidents among packers. After an evaluation of the costs of the change, we have presented a rigorous econometric analysis to assess how many accidents have been prevented because of the change so as to compute the direct and indirect costs avoided in relation to such accident reduction. We showed that, paradoxically in our modern work environment, the "demechanization" of the handling system has been profitable for the enterprise.

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, unexpectedly, the "demechanization" of certain industrial processes may be a promising tool to reduce the costs and suffering related to workplace accidents.

TABLE 1: WORKPLACE ACCIDENTS
SAQ, MONTREAL WAREHOUSE

	1993	1992	1991	1990[1]	1989	1988	1987	TOTAL
Accidents:								
With Loss of time	18	35	57	31	48	44	26	259
Without Loss of Time	26	35	62	50	28	55	38	294
Recurrences	4	7	4	2	4	8	5	34
Total	**48**	**77**	**123**	**83**	**80**	**107**	**69**	**587**
Workdays Lost Due to Back-related Injuries[3]								
Back-related Injuries	285	469	733	1274	600	413	216	3759.2
Other Accidents	362	400	853	289	573	1000.2	290	3998
Total	**647**	**869**	**1586**	**1563**	**1173**	**1413.2**	**516**	**7767.2**
Back-related Injuries:								
Number	16	25	33	18	25	20	16	153
Perrcentage	33.3%	32.4%	26.8%	21.7%	31.3%	18.7%	23.2%	31.2%
Workers in the Sample	274	264	270	280	224	234	205	1751
Accidents/100 Workers	17.51	29.16	45.55	29.64	35.71	45.73	33.66	33.52

Notes:

1: Workers were on strike from October 1990 to March 1991.
2: Recurrences indicated are either with or without workday losses.
3: Workdays lost after June 30 are reported the following year.

TABLE 2

COSTS AND BENEFITS OF THE INTERVENTION IN CURRENT AND 1989 DOLLARS

	Year	Current $	$ 1989	
BENEFITS				
Indirect Costs	1991	$83 936.26	$67 514.94	
	1992	$22 424.67	$83 692.07	
	1993	$19 158.84	$96 087.73	
				$247 294.74
Direct Costs	1991	$72 815.39	$58 569.76	
	1992	$22 424.67	$74 746.89	
	1993	$18 811.03	$86 917.52	
				$220 234.17
Reduction in the Number of Broken Bottles	1991	$229 317.00	$184 453.34	
	1992	$267 702.00	$193 119.89	
	1993	$263 826.59	$170 694.33	
				$548 267.56
Labour Cost Savings	1990	$26 600.27	$23 856.74	$23 856.74
	1991	$206 613.00	$166 191.16	$166 191.16
	1992	$995 771.00	$718 347.98	$718 347.98
	1993	$1 025 644.00	$663 585.94	$663 585.94
				$1 571 981.80
Total of Benefits:				$2 587 778.28
COSTS				
Honoraries (Engineering)	1990	$338 370.00	$303 470.85	$303 470.85
Equipments				
- Shelving System	1990	$427 034.00	$382 990.13	$382 990.13
- Pallet truck	1990	$346 268.00	$310 554.26	$310 554.26
- Forklift Trucks	1990	$179 889.00	$161 335.43	$161 335.43
- Pallet Distributor	1990	$40 668.00	$36 473.54	$36 473.54
				$891 353.36
Building (Modifications)	1990	$367 627.00	$329 710.31	$329 710.31
Early Retirement Compensations	1992	$175 000.00	$126 244.78	$126 244.78
				$1 650 779.31
		Net Present Value:		$936 998.97

TABLE 3
SAMPLE DESCRIPTIVE STATISTICS

Variable	Definition	Mean	Standard Deviation
Workplace Accidents	Accidents and recurrences per worker per year	0.3341	0.6691
Back-related Injuries	Back-related injuries per worker per year	0.0736	0.2782
Age	Age of worker	38.13	9.01
Experience	Years of experience as a S.A.Q. worker	13.26	7.71
Wage	Hourly wage according to the collective agreement	15.4	1.64
Preparation	Portion of the year worked at the preparation service	0.304	0.424
Delivery	Portion of the year worked at the delivery service	0.14	0.34
Receiving	Portion of the year worked at the receiving service	0.143	0.329
Shipping	Portion of the year worked at the shipping service	0.072	0.246
Absenteeism	Hours of absenteeism per worker per year	90.36	118.26
Overtime	Overtime hours per worker per year	111.91	152.26
Status	Worker's status; regular=0, RNT=1	0.31	0.463
Grievances	Number of grievances per worker per year	0.261	0.703
Strike	Six month strike in 1990 (0, 1=1990)	0.16	0.367
Year after the strike	Year following the 1990 strike (0, 1=1991)	0.154	0.361
Time-movements study	1992=1, 0 otherwise	0.151	0.358

Variable	Definition	Mean	Standard Deviation
Service * newsystem	Multiplication of both variables	0.11	0.545
Accident during the precedent year	1 if worker had a workplace accident during the previous year, 0 otherwise	0.206	0.405
Newsystem	Implementation of the new system: 1991=1, 1992=2, 1993=3, 0 otherwise	0.925	1.145

TABLE 4
RESULTS OF THE REGRESSION ANALYSIS (T-RATIO)

	Model 1	Model 2	Model 3
Intercept	-0.48019 (-0.370)	-0.80451 (-0.627)	-0.82475 (-0.642)
Age	-0.99657E-02 (1.199)	-0.94613E-02 (1.150)	-0.94649E-02 (1.150)
Experience	-0.26029E-01** (-2.052)	-0.26119E-01** (-2.050)	-0.26048E-01** (-2.044)
Wage	-0.45824E-01 (-0.456)	-0.26541E-01 (-0.266)	-0.24375E-01 (-0.244)
Delivery	0.59345** (3.242)	0.48211** (2.724)	0.45852** (2.643)
Shipping	-0.41922E-01 (-0.180)	-0.88311E-01* (-0.363)	-0.10889E-01* (-0.450)
Receiving	0.16251 (1.010)	0.13644 (0.850)	0.11857 (0.755)
Absenteeism	-0.19171E-03* (-0.331)	-0.21724E-03 (-0.369)	-0.20999E-03 (-0.357)
Overtime hours	0.19466E-03 (0.432)	0.23477E-03 (0.530)	0.24631E-03 (0.555)
Worker's status	-0.82384** (-5.257)	-0.76067** (-4.922)	-0.76487** (-4.953)
Grievances	0.15079** (2.486)	0.13081** (2.159)	0.13064** (2.165)
Strike	-0.20685 (-1.317)	-0.25817 (-1.632)	-0.25568 (-1.616)
Year after strike	0.46602** (3.133)	0.42277** (2.744)	0.40395** (2.654)
Time-movements study	0.31594* (1.789)	0.20537 (1.119)	0.16311 (0.933)
Service*new system	0.95645E-01 (0.773)	0.92018E-01 (0.747)	-----
New system	-0.25242** (-3.644)	-0.27490** (-4.000)	-0.24995** (-4.043)
Accident during precedent year	-----	0.61095** (5.519)	0.61124** (5.524)
Variance parameter	0.70432** (4.322)	0.59784** (3.891)	0.59844** (3.898)
Likelihood Function	-1264.188	-1247.703	-1247.956

(*) Significant at a 5% level. (**) Significant at a 10% level.

TABLE 5

NUMBER OF PREVENTED ACCIDENTS
SAQ, MONTREAL WAREHOUSE

Value of NEWSYSTEM	Average Frequency	Absolute Number of Accidents	Prevented Accidents	Total Number of Prevented Accidents
0	0.3293	82.26	Not Relevant	Not Relevant
1	0.4125	103.20	26	26
2	0.1869	46.74	12	38
3	0.1540	38.52	10	48

TABLE 6

SENSITIVITY ANALYSIS

	5%	10%	15%
Σ Benefits	$3 108 279.18	$2 696 412.85	$2 357 037.42
Σ Costs	$1 770 082.06	$1 676 803.73	$1 593 200.99
Net Present Value	$1 338 197.12	$1 019 609.12	$763 836.43

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