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A Quantitative Method for Assessing Cost-Effectiveness of Safety Projects

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Abstract: - Many case studies about occupational safety have been recently reported in manufacturing companies. But there are few studies being aimed at analyzing the costs and benefits of these projects about safety improvement in the workplace. This may be due to the difficulty of quantifying the benefits of a safety project, especially the less-tangible benefits. Establishing a methodology was therefore attempted in this study to assess cost-effectiveness of safety projects. The possible costs and benefits associated with a safety project were classed into several categories. The sub-items for each category were then identified. Contingent Valuation Method (CVM) was applied in quantifying less-tangible benefits. The proposed methodology can be used to aid safety engineers in analyzing the costs and benefits with regard to safety improvements in the factory.

Key-Words: - Engineering economics; Quantitative method; Cost-benefit analysis; Safety improvement

1 Introduction

Many enterprises conducted numerous industrial safety projects, but didn't analyze their cost-effectiveness. This was due to some difficulties still need to be overcome in assessing costs and benefits of the safety projects. On the one hand, a safety engineer may not have enough knowledge and capability to analyze the cost-effectiveness of his/her safety projects. On the other hand, it remains very difficult to assess monetary value of the less-tangible benefits with regard to safety improvements in the factory. The less-tangible benefits may be enhancement of safety in the workplace or decrease in work-related risk factors imposed upon the workers. These less-tangible benefits cannot be bought or sold in the marketplace, and therefore are considered as 'non-market goods'. Non-market goods can not be easily presented in terms of monetary values. However, an employer always wants to know whether or not the safety project is good value for money. This research was thus tried to propose a methodology for solving the above-mentioned problems.

Measuring the costs of safety projects usually is easier than measuring the benefits because some cost estimation methods have been suggested [1, 2, 3]. In addition, the necessary accounting data associated with the costs of safety projects often already are available within the manufacturing companies.

Many of the benefits of safety projects, such as increase of monthly outputs, saving of reduced injury loss, saving of reduced asset loss, can be determined by collecting accounting data associated with operations and accidents [4, 5]. But, it takes several years after safety improvement actions to completely perceive the benefits resulting from the safety project. Furthermore, some benefits of safety projects are invisible or less-tangible, as mentioned early. These are much harder to quantify in specific currency amounts, but never the less should be recognized. Two of these less-tangible benefits particularly worth noting are increased employee commitment and improved corporate image, as suggested by Hendrick [6]. But he did not provide any methods to quantify the less-tangible benefits in financial terms.

Fortunately, non-market goods have recently been valued with the contingent valuation method (CVM). The CVM was developed in the environmental field to assess the value of public goods such as environmental quality and natural resources [7, 8, 9]. This method was later also applied to value the changes in health care or safety condition [10, 11, 12, 13]. The CVM usually adopts surveys to find out the respondents' willingness-to-pay (WTP) for improvements on specific conditions. The WTP survey is an appropriate measure in a situation where people want to acquire the non-market goods [13].

Since the less-tangible benefits derived from a safety project also have the characteristics of non-market goods, the application of the CVM is considered suitable for determining the economic value of the less-tangible benefits. For this reason, the CVM is applied to determine the monetary value of the less-tangible benefits in this study. The proposed methodology combined the traditional business case model and the newly CVM to assess the cost-effectiveness of safety projects. Finally, a practical safety improvement project was adopted to illustrate the practicability of the proposed methodology.

2 Methodology

The first step of a cost-effectiveness analysis is to collect any cost data associated with the safety project. Section 2.1 provides the descriptions of the five possible cost categories. After the safety improvement actions, all benefits resulting from the safety project should be assessed. Six possible benefit categories are explained later in section 2.2. If there are any less-tangible benefits derived from the improvement actions, the WTP questionnaire should be designed and used to evaluate the monetary value of the less-tangible benefits. A detailed guide for designing the WTP questionnaire is provided in section 2.3. After obtaining the monetary values of the costs and benefits, they can be used as the input data for analyzing the cost-effectiveness by the traditional business case model, as mentioned in section 2.4.

2.1 Cost categories

Possible costs occurring in conducting a safety project in the workplace can be classified into five categories as described below:

(1) Risk identification fees
The expenditures for identifying the work-related risk factors in the workplace and studying their impacts on the workers are risk identification fees.

(2) Research and design fees
After risk identification, it is required to research and design improvement actions that will eliminate or reduce the work-related risk factors. All the activity costs incurred during researching and designing improvement actions are considered as research and design fees.

(3) Administrative improvement costs
Administrative improvement means making changes in management systems, work processes, standard operation procedures, or the other regulations in order to prevent workers from exposure to the work-related risk factors. These changes may also be accompanied with employee down time. All the costs resulting from the administrative improvement activities belong to the administrative improvement costs.

(4) Hardware improvement costs
Hardware improvement is any capital investment in construction, equipments, tools, and the other physical assets to eliminate or reduce the work-related risk factors. This kind of improvement may also be accompanied with employee down time. All the costs resulting from the hardware improvement activities are included in the hardware improvement costs.

(5) Monthly overheads
Monthly overheads imply the monthly operating costs associated with the maintenance following the improvement actions. The reduced productivity or sales derived from the improvement actions should also be considered as overheads.

2.2 Benefit categories

Possible benefits resulting from the improvement actions in the workplace can be classified into six categories as described below:

(1) Increase of monthly outputs
Improved productivity resulting from the improvement actions may bring the increase of monthly outputs. The increase of outputs can be calculated as the increased amount of some product per month multiplying by its gross margin.

(2) Saving of monthly working time
The safety project may make the workers more efficient. This result can lead to saving of working time. The motion and time study should be employed to confirm how much time is saved. The saving of working time can be calculated as the amount of working hours saved per month

multiplied by the corresponding average wages per hour.

(3) Saving of monthly operation costs
The operation costs may be reduced by the safety improvement actions. The saving of monthly operation costs can be determined by collected the accounting data for several months.

(4) Saving of reduced injury loss
The safety improvement actions may reduce the accidents. If the improvement actions lead to fewer injury cases than those before, then the saving of reduced injury loss should be considered as a benefit.

(5) Saving of reduced asset loss
In addition to injury loss, accidents usually are also accompanied with the asset loss such as work-in-process damage, materials damage, products damage, factory rebuilding or repair, equipment purchase or repair, and facility purchase or repair. If the safety improvement leads to fewer accidents than those before, the saving of reduced asset loss should be considered as a benefit.

(6) Less-tangible benefits
Some benefits resulting from the safety project can't be included in the accounting system. These benefits are called less-tangible benefits such as the reduction in ill-related risk factors imposed upon the workers, increased employee commitment, and improved corporate image. The monetary values of these benefits can be estimated with the WTP questionnaire.

2.3 WTP questionnaire design

The less-tangible benefit evaluation questionnaire or the WTP questionnaire is aimed at collecting the workers' willingness-to-pay for the improvement actions of the safety project. In order to make each respondent understand the project, the first part of the WTP questionnaire summarizes what changes have taken place after executing the project.

The second part of the WTP questionnaire comprises questions about the WTP for the less-tangible benefits accompanying the executed safety project. The mean WTP value of the sampled workers can be an estimator of the population mean, if the sample size is large enough.

2.4 Return on investment

The total cost (*named 'C'*) was defined as the initial investment of the safety project. We suggested that there are no other investment costs at the end of each year during the service life of the safety project. The service life of the project (*named 'n' years*) should be estimated first. The benefit every year (*named 'B_t'*) is suggested to produce at the end of the t^{th} year. Therefore, the total benefit should be converted into present worth according to some given interest rate (*named 'i'*) or called discount rate. Then, the net present worth (NPW) of the safety project can be calculated by the equation (1). The return on investment (ROI) of the project can be easily calculated by dividing the NPW by C, as shown in the equation (2). All these calculations can be performed automatically by a computer application.

$$NPW = \sum_{t=1}^{n} \frac{B_t}{(1+i)^t} - C \quad (1)$$

$$ROI = NPW / C \quad (2)$$

3 An illustrative practical example

The illustrative safety project had been executed in a semiconductor manufacturing company in 2003. The OSHA's musculoskeletal disorders checklist was applied in identifying the work-related risk factors in the 300-mm wafer fabrication. Three main work-related risk factors in the workplace were found.

The safety improvement actions included two lectures about how to prevent musculoskeletal disorders and three posters for reminding workers of the standard postures of transporting 300-mm wafer lots. These actions were expected to reduce musculoskeletal disorder and injury occurrences on the workers. The proposed cost-effectiveness analysis methodology is applied to assess the return on investment of executing this safety project.

The costs of the safety project were retrieved from the historical accounting data. The three cost categories were risk identification fees, research and design fees, and administrative improvement cost. The total investment cost was TWD 803,400.

Since there were no significant changes in the outputs, working time, operation cost, injury and assets loss by accidents before and after ergonomic intervention, these benefit categories were assigned zero values.

The less tangible benefit was evaluated with the WTP questionnaire. In the WTP survey, 231 effective responses were obtained from 285 workers in the semiconductor manufacturing company. The mean WTP of the 231 workers was 4,169 TWD per year. Taking the mean WTP of the 231 workers as the estimator for the population mean, the total amount of all workers' WTP per year can be calculated as 4,169 × 285 = 1,188,165 TWD per year.

The discount rate at that time was 2.98% and the years of useful life of this investment was estimated as one year. The present value of the total benefit was 1,188,165 / 1.0298 = 1,153,782 TWD. Finally, the return on investment (ROI) was calculated as (1,153,782 – 803,400)/ 803,400 = 43.6%.

4 Conclusion

The proposed methodology not only can be used to quantify the less-tangible benefits of safety projects but also can be applied to judge the effectiveness of safety projects. The ROI of the illustrative practical project was estimated to be 43.6% demonstrating good economic efficacy for the safety improvement. But, it should be noted that the less-tangible benefits derived from the WTP responses are not actual financial benefits until the workers really pay the money. In general real cases, the employers usually just want to understand whether the safety improvement actions are worth investing, instead of getting the money paid by the employees.

This study provided a timesaving and easy method to analyze the cost-effectiveness of a safety improvement project in terms of business case. In the demonstrative example, only one month was required to conduct the WTP survey after the safety improvement actions. In addition, the ROI of the project can also be estimated easily. The estimated ROI can be considered as an important index to criticize the economic value of the safety project, and it is also helpful information for decision-making in safety investment in the future.

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