Vol. 7, No. 2, pp. 23-26, December 2008

INTERNATIONAL JOURNAL OF SAFETY
www.kosos.or.kr

A Framework for Control of Safety Budget-Industrial Accidents Relationship

Gi Heung Choi*

Department of Mechanical Systems Engineering, Hansung University, Seoul 136-792, Korea

(Received May 2, 2008; Accepted November 14, 2008)

Abstract : This study focuses on the issue of control performance of safety budget for preventing and reducing industrial accidents in Korea. The effect of safety budget such as industrial accident prevention fund on the safety performance is statistically examined first. The role and control performance of industrial accident prevention fund is particularly addressed to reduce the related accidents. The effectiveness of the industrial accident prevention fund-industrial accident relationship is then explained with a simple PI control mechanism.

Key words: safety assessment, safety budget, accident rate

1. Introduction

Safety activities by government, industries and non-government organizations (NGOs), in general, require the safety budget whose source may vary depending on the types of those activities. Design of safety-guaranteed industrial environment is, in particular, important since it determines the ultimate outcomes of industrial activities involving safety of workers. Looking back the past 20 years, the accident rate in Korea drastically reduced to less than half of that in 20 years ago. Despite the increasing efforts to prevent and reduce the industrial accidents these days, however, the accident rate stays almost constant over the last few years. Table 1 indicates that such point clearly. Since 1997, the rate had not improved much around the value of between 0.7% and 0.8%.

Safety policies and safety management of in industrial work places in Korea is known to be non-systematic and inefficient, which result in more than 2,400 cases of death in the year 2007. In 2007, more than 80,000 workers had been reported injured. Compared to the current safety management system, more realistic and efficient safety management system is, therefore, required to prevent the industrial accidents.

Table 2 shows that fatality rate in Korea (number of death in industrial accidents per 10,000 workers) is

*Corresponding author: gihchoi@hansung.ac.kr

Table 1. Accident rate and total number of death in industrial accident over the 20 years

Year	Accident rate	Total number of death in industrial accident
1987	2.66	1,761
1988	2.48	1,923
1989	2.01	1,724
1990	1.76	2,236
1991	1.62	2,299
1992	1.52	2,429
1993	1.3	2,210
1994	1.18	2,678
1995	0.99	2,662
1996	0.88	2,679
1997	0.8	2,742
1998	0.68	2,212
1999	0.74	2,291
2000	0.73	2,528
2001	0.77	2,748
2002	0.77	2,605
2003	0.9	2,923
2004	0.85	2,825
2005	0.77	2,493
2006	0.77	2,453
2007	0.72	2,406

Table 2. Industrial accident rate in major countries

Country	Number of death per 10,000 workers due to industrial accidents
Korea	1.47
Japan	0.3
Germany	0.26
UK	0.07
France	0.35
Sweden	0.14
Australia	0.14

about 5 to 10 times that of most of Japan, USA and the major European countries. Note that USA and UK use different measures for calculating accident rate and, therefore, these values in Table 2 are not directly compatible with data in other countries.

It is noticed from Table 1 and Table 2 that the current safety management system is neither able to cope with the increasing demand for safer work place nor it is effective in terms of reducing the accidents and saving lives and properties of workers and industries. Then, a new method to enhance the overall performance of safety management system must be devised and implemented.

Among many safety policies that affect the safety of workers in general, safety budget is known to have the fastest and most significant influence on preventing and reducing industrial accidents. Another advantage of safety budget over the other safety policies is that it is easily controlled and, therefore, easy to evaluate its performance. Among various types of safety budget, attention must be paid to industrial accident prevention fund which is distributed and controlled by either the government or the agencies in Korea, and its control performance for prevention of industrial accidents needs to be evaluated in relationship with the accident rate.

This study focuses on the issue of control performance of safety budget for preventing and reducing industrial accidents. Specifically, the effect of safety budget such as industrial accident prevention fund on the safety performance in Korea is statistically examined first. The role and control performance of industrial accident prevention fund is particularly addressed to reduce the related accidents. The effectiveness of industrial accident prevention fund-industrial accident relationship is then explained with a simple PI control mechanism.

2. Safety budget and the accident rate

Figure 1 and Figure 2 graphically show the trend of the accident prevention fund and the accident rate over the past 20 years (from 1987 to 2007). In the figures, the actual data were fitted to exponential model of the form

$$\alpha_1 + \beta(\alpha_2 - \alpha_1)(1 - e^{-\gamma t}) \tag{1}$$

where α_1 is the initial value of the data concerned (e.g., either the accident prevention fund or the accident rate), α_2 is the final value, β is the proportionality constant, γ is the time constant and t is the year passed since the starting year. Ignoring various factors that might affect the accident rate other than safety budget, the figures indicate a remarkable correlation. As the efforts for prevention in terms of budget saturated over the last several years, the accident rate appears to converge to the value of 0.7% and stays constant thereafter.

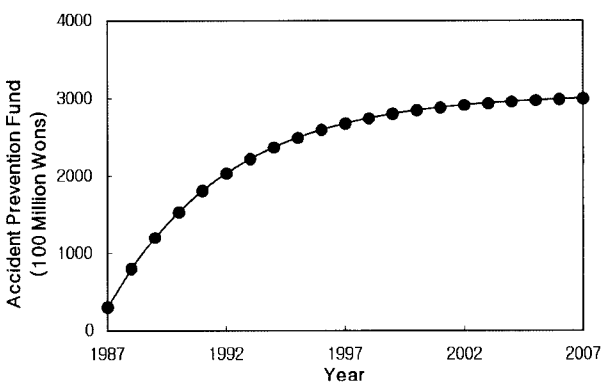

Fig. 1. Accident prevention fund expenditure for the past 20 years in Korea

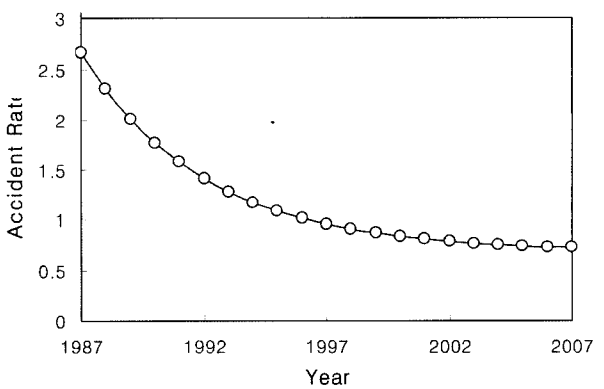

Fig. 2. Accident rate for the past 20 years

The results in the figures strongly implies that the safety budget such as industrial accident prevention fund needs to be increased to further decrease the accident rate to a level in advanced countries, 0.3% or so which is the rate in advanced countries such as Japan shown in Table 2.

3. A framework for control mechanism

In order to model the industrial accident prevention fund-industrial accident relationship and find a useful mechanism that can control the accident rate, a feedback model of safety management system is considered as shown in Figure 3. In the figure, the system model (open-loop system) is a work place-process or worker-behavior model with industrial accident prevention fund as the input and the actual industrial accident rate as the output. Any difference between the target accident rate (input to the feedback system) and the actual accident rate (output of the feedback system) works to drive physical and social efforts to improve safety environment. The actual rate is the result of all the safety activities based on the physical and social feedback. For example, one may invest on renewing and automating equipments and facilities, educate his employees to comply with safety rules at their work places, ask government to update or upgrade any unreasonable or ineffective safety-related laws. All these are the control variables to drive the safety management system as targeted. After all, the government and or its agency will need safety budget to perform all these safety activities and achieve safety target. Then, a question arises as to how effectively the government can control the situation with safety budget. In this study, the safety budget such as industrial accident prevention fund as a feedback control variable and a framework to enhance its control performance in the feedback model are suggested.

According to Figure 2, the accident rate does not seem to converge to the target value is 0.3 or so in Japan and major European countries. Assuming that a system model of work place-process or worker-behavior model in Korea has a typical second order system in Equation (2) with industrial accident prevention fund as input, such statistical data in Table 1 indicates that the system model in Korea have a form of type zero system (N=0 in Equation (2)) and so does the system transfer function. Type zero system has no pole on the origin of s-plane and, therefore, inherently has no integral action in the system. The transfer function between the industrial accident prevention fund (system input in Figure 3) and the accident rate (system output) can be assumed to have a more generic second order form as

$$G(s) = \frac{1}{s^N(s^2 + 2\xi\omega_n s + \omega_n^2)} \tag{2}$$

The input-output relationship in Figure 1 and Figure 2 is a typical example of type zero system with only a proportional gain in negative feedback. In order to eliminate the permanent error between target accident rate and the actual rate, one needs to include a integral action in the feedback controller. The most widely used form of a feedback controller is a PID controller. PID controller is a controller with three terms in which the output of the controller is the sum of a proportional term, an integrating term and a differentiating term, with an adjustable gain for each term. This controller typically has functional simplicity and exhibits robust control performance in a wide range of conditions. The selection of the three gains of PID controller is basically a search problem in a three dimensional space. However, in case discussed in this study, a gain for differentiating term may be ignored for simplicity.

Next, whether the integral action can reduce the actual accident rate to the target value and if possible how much more budget is needed to accomplish the control objective, a PI controller with a traditional form can be introduced in the formulation as

$$G_c(s) = K_p + K_i\frac{1}{s} \tag{3}$$

The system in Equation (2) can be identified and the appropriate gains for proportional and integral actions in the feedback controller cab be found to drive the actual accident rate to the target value.

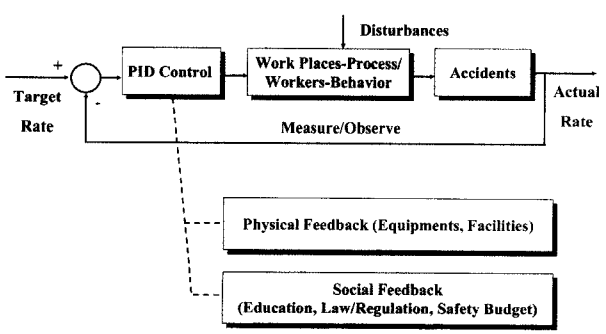

Fig. 3. Feedback control model of industrial accident prevention fund – industrial accident rate relationship

4. Conclusions

In this study, the effect of safety budget such as industrial accident prevention fund on safety perfor-

mance in Korea is statistically examined. A strong correlation between industrial accident prevention fund and industrial accidents suggests that a framework for feedback model with a simple PI control can perform control target to prevent and reduce the industrial accidents. The role and control performance of industrial accident prevention fund is particularly addressed to reduce related accidents. Classical control theory indicates that a simple PI control can drive the actual accident rate to the target value. The amount of safety budget such as the industrial accident prevention fund required to reduce the accident rate from the current level to the target level, however, needs to be further evaluated.

Acknowledgement

This study was supported by the Hansung University in the year of 2008.

References

[1] A. Raouf and B.S. Dhillon, *Safety Assessment – A Quantitative Approach*, Lewis Publisher, 1994

[2] Gi Heung Choi, "Application of Information-theoretic Measure (Entropy) to Safety Assessment in Manufacturing Processes", Int. J. Safety, Vol.4, No.1, 2005

[3] M. Ramulu, D. Kim and Gi Heung Choi, "Frequency Analysis and Characterization in Cutting of Glass Fiber Reinforced Composite", Composite (A), Vol.34, pp.949-962, 2003

[4] J.E. Shore and R.M. Gray, "Minimum Cross-Entropy Pattern Classification and Cluster Analysis", IEEE Trans. On Pattern Analysis and Machine Intelligence, Vol. PAMI-4, No.1, pp.11-1103, Jan., 1982

[5] Gi Heung Choi, *Product Design and Manufacturing – A Systems Approach*, Lecture Note, Department of Mechanical Systems Engineering, Hansung University, 2005

[6] Nam P. Suh, "The Principles of Design", Oxford University Press, 1990

[7] M. Zinn, O. Khatib, B. Roth and J. Salisbury , "Playing It Safe", IEEE Robotics and Automation Magazine, pp.12-21, June, 2004

[8] A. Bicchi and G. Tonietti, "Fast and Soft Arm Tactics", IEEE Robotics and Automation Magazine, pp.22-33, June, 2004