The role of legislation and regulation in safety and health in mines

by J.M. Stewart*

Synopsis

Mining fatality rates in many countries have not changed substantially over the past ten years. This demonstrates not only that there is an inherent risk in mining, but also that current approaches to improving safety need to be re-thought. An analysis of productivity and fatality data in the United States, United Kingdom, and South African coal-mining industries shows that the impact of legislation on safety is overlain by other significant factors. Although improvements in safety and productivity usually occur together, the data warn that safety legislation can sometimes cause a significant reduction in productivity. Based on the data and experience considered, it is concluded that legislation should be aimed at creating a framework within which a positive attitude towards the implementation of more productive and safer mining methods, work practices, and

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Introduction

The production of minerals without any form of accident must be the ultimate objective of any mine manager worth his position. Nevertheless, and despite the very significant improvements in safety that have occurred in most mining countries over the past sixty years, many miners are injured, or lose their lives at work, every year. This loss of life is demonstrated in Figure 1, which shows fatality rates over the past ten years for coal mining in some of the world's major coal-mining countries. Not only are these countries leading coal producers but, according to a recent report[1], along with Canada they are also the safest. A particularly disturbing feature of this figure is that the fatality rates in most of these countries have not exhibited any notable downward trend over this ten-year period. This observation is true of other types of mining too, an example being shown in Figure 2 for gold mining in South Africa[2]. Two important conclusions emerge.

Firstly, the relative lack of improvement in fatality rates over the past ten years indicates that the approach towards safety, and the efforts to improve it, need to be re-thought. Conversely, the persistent occurrence of fatalities in these leading mining countries warns that, in principle, a situation may be reached where further incremental safety efforts yield insufficient benefit to be justified, notwithstanding the continued occurrence of fatal accidents. In such a situation, the risk giving rise to these persistent fatalities may be regarded as a *residual safety risk*. These conclusions indicate that, along any path towards improved mine safety, it is inevitable that a key issue must become that of striking a balance between *safety effort* and *residual safety risk*. Such a balance is not easily struck since there are many difficult issues that must be examined.

The purpose of this paper is to contribute to the quest for safer mines by examining past experience across a broad spectrum, considering the difficult issues identified, and pointing a way forward.

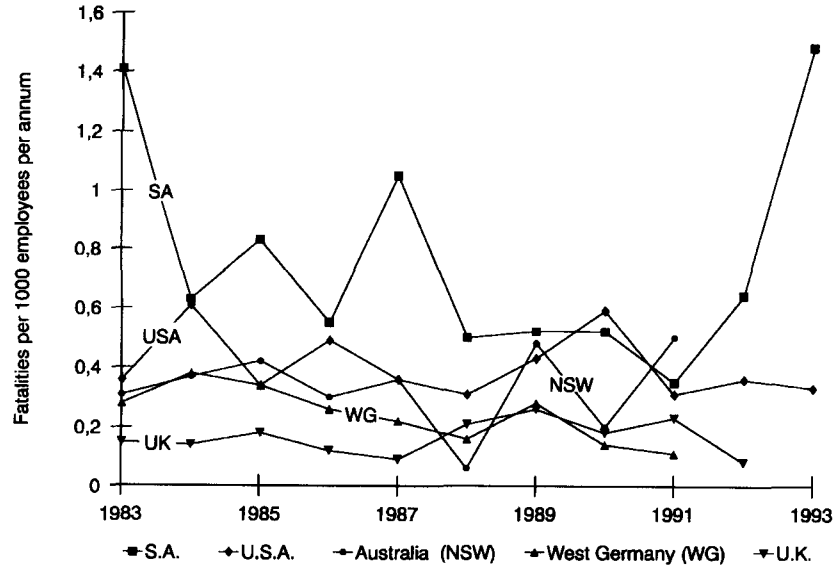

Figure 1—Historical record of fatalities in coal mines for a number of the world's major coal-mining countries

technology can flourish, rather than attempting to enforce excessively prescriptive provisions. This latter approach is even more problematic when safety standards and legislation are transferred from well-developed to less-developed countries.

A legislative framework in which the mine manager is required to take all reasonably practicable measures to procure safe working conditions in accordance with mine-specific codes of practice is outlined. Within that framework, the value of adopting widely accepted standards is recognized. A performance-based external audit arrangement is outlined as a basis for ensuring that detailed attention is focused on those areas most needing improvement.

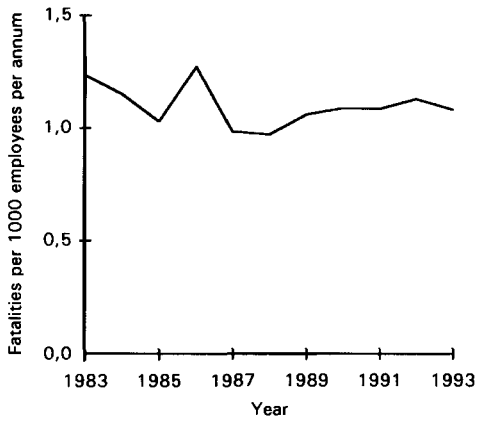

Figure 2—Historical record of fatalities on South African gold mines

Societal risks and judgements

Given the inevitable need to strike a balance between *safety effort* and *residual safety risk*, it is important to identify, as a point of reference, the framework of risks to which society is exposed. Virtually every form of human endeavour involves some form of risk, and over the years a framework of existing risks has thus evolved out of human experience. Implicitly or explicitly, that framework is fundamental to the assessment of acceptable risk in relation to any given risk factor. In this regard, the view[3] expressed by the International Commission for Radiological Protection (ICRP) is particularly instructive. Their view is as follows:

'The Commission's multi-attribute approach to the selection of dose limits necessarily includes social judgements applied to the many attributes of risk. These judgements would not necessarily be the same in all contexts and, in particular, might be different in different societies. It is for this reason that the Commission intends its guidance to be sufficiently flexible to allow for national or regional variation.'

It is worth noting that the ICRP adopted, as the basis of its recommendations, a 5 per cent risk of death due to occupational exposure to radiation over a working life of 50 years. However, a rather more meaningful way of assessing and comparing risks, and of constructing the desired framework of risks, is to represent them in terms of the loss of life expectancy associated with exposure to the risk in question. This approach has been explored extensively by Cohen[4,5], and a summary of his findings relevant to this paper is presented in Table I. Also given in the table are data from other sources[6].

While the bulk of these data refer only to the USA, they confirm mining as one of the more hazardous occupations. However, the data also clearly demonstrate that the contribution of lifestyle factors to loss of life expectancy far outweighs that attributable to occupational risks. Apart from providing a framework for judging acceptable risks, the data in Table I illustrate the importance of giving due consideration to possible linkages between occupational and societal risk factors.

Table I

Loss of life expectancy (LLE) associated with various risk factors

Risk factor	Loss of life expectancy	
	Days	Years
Societal		
Alcoholism	4000	11,1
Poverty	3600	10,1
Smoking > 20 cigarettes per day	2400	6,7
Heart disease	1600	4,4
Cancer	1200	3,3
Overweight > 20 per cent	1100	3,1
Motor vehicle accidents	200	
Bicycle accidents	6	
Living at altitude: 1500 m vs sea level[4]	5	
Occupational		
Agriculture	320	
Construction	227	
Mine and quarry	167	
Transportation — utility	160	
Trade	27	
Air crew flying 20 hours per week for 30 years	20	
Recreational		
Mountain climbing—dedicated climbers	110	
Parachuting	25	
Hang gliding	25	
Sail planing	9	
Boxing	8	
Scuba diving	7	

Effectiveness of safety regulations

Given that safety regulations are promulgated for the purpose of achieving safety in mines, it is important to examine both their effects and their effectiveness in practice. In this regard, an analysis of the extensive data available for the US and UK coal-mining industries is particularly instructive, in regard to both production and safety performance.

Effect on productivity

In 1969 the Federal Coal Mine Safety and Health Act was introduced in the USA. At that time it was described as the 'strongest single code of health and safety' ever known in the USA[7]. In the ten years that followed, there was a massive drop in coal-mine productivity[8,9]. This is shown in Figure 3. Although a number of authors[10–17] make it clear that various factors contributed to this fall, they also indicate that the Act was one of the major contributors. In particular, one of the more detailed investigations[12] concluded that the Act was the major cause of the productivity decline from 1970 to 1973. These studies point out that, in order to meet the newly imposed requirements for protecting and monitoring the health and safety of miners, mine operators had to add personnel or transfer shift workers from mining to safety-related activities[17].

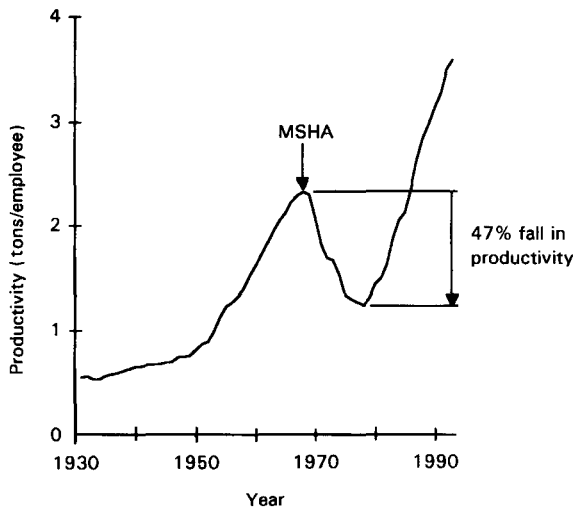

Figure 3—Productivity data for the US underground coal-mining industry (MSHA = Mine Safety and Health Act 1969)

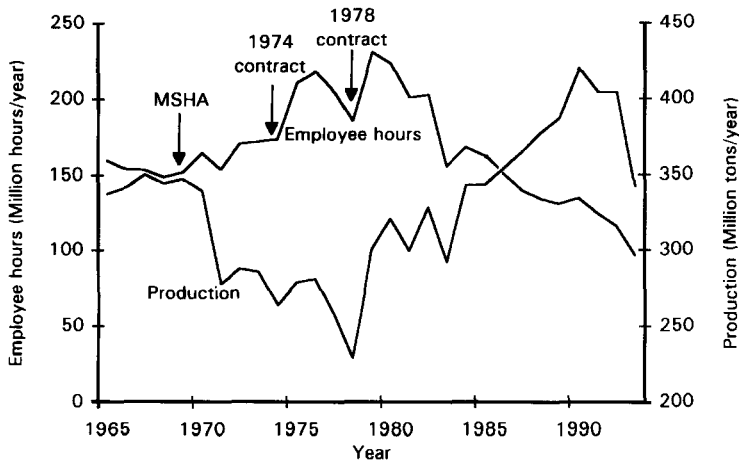

Figure 4—Employee hours and tons produced in the US underground coal-mining industry

The increased attention to health and safety resulting from the Act was reflected also in union activity, and through the activities of an enlarged inspectorate. These responses to the Act caused productivity to fall and, given their nature, it will be evident that they must also have caused an increase in the costs of both production and the inspectorate.

The continued decline in productivity from 1974 to 1978 has been attributed largely to labour unrest and to a very sharp rise in coal prices due to the oil crisis[12]. In particular, the contract agreed with the unions in 1974 caused an increase in manpower levels[18], and the negative effect of this change on productivity was exacerbated by wildcat strikes. Production and manpower levels over this period, and beyond, are shown in Figure 4.

Figure 3 shows that, from 1979, productivity in US underground coal mines started increasing as rapidly as it had fallen in the preceding decade. The explanation for this sudden turn-around is less clear than for the sudden fall, but the available literature[15,17,19] indicates that the contract agreed with the unions in 1978, together with a sharp change in coal price trends, were the primary reasons. That literature also indicates that technological advances, particularly the increased use of highly productive longwall mining methods, contributed significantly to the turn-around. Finally, it appears that improved technology, and a steady improvement in the relationship between labour and mine management, were then primarily responsible for the continued improvement in productivity.

Recognizing that changes in the coal price can have a strong influence on productivity[20], productivity trends in other countries during the 1970s have also been examined. Productivity data for the UK and South African coal-mining industries are presented in Figure 5. Notwithstanding the inclusion of data for surface coal mining in the curves shown in Figure 5, the relatively steady upward trend in productivity for these two countries during the 1970s suggests that labour unrest was the more dominant cause of the fall in US coal mine productivity after 1974. However, had there not been a massive 278 per cent increase in coal price, from around US$6 in 1970 to US$24 per ton in 1979[21], there can be little doubt that the 47 per cent fall in productivity would have devastated the US coal-mining industry.

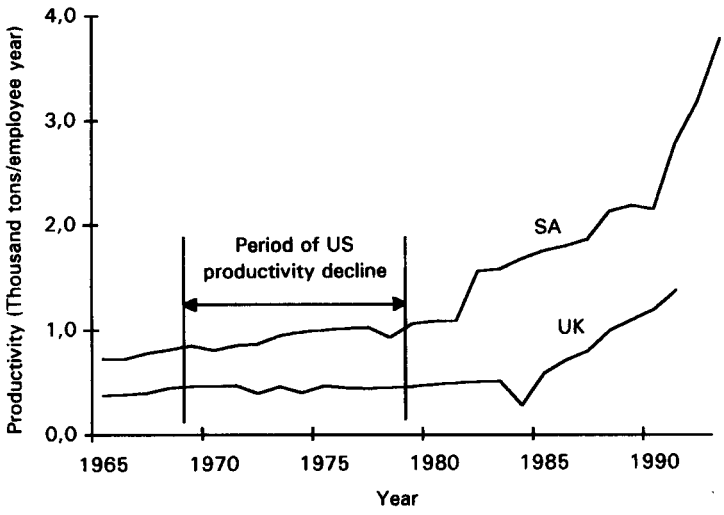

Figure 5—Productivity in the UK and SA coal-mining industries

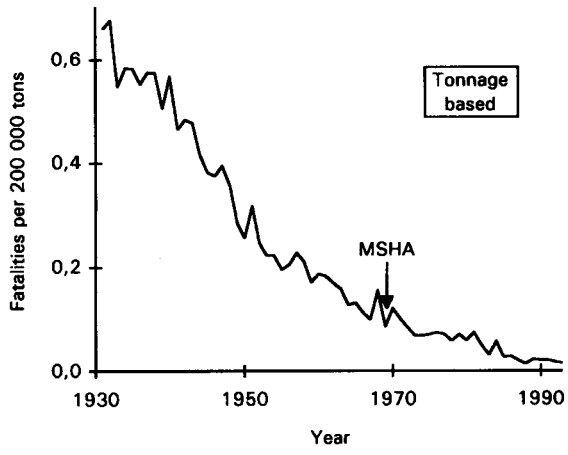

Figure 6—Historical record of fatalities in US underground coal mines, based on tons produced (MSHA = Mine Safety and Health Act 1969)

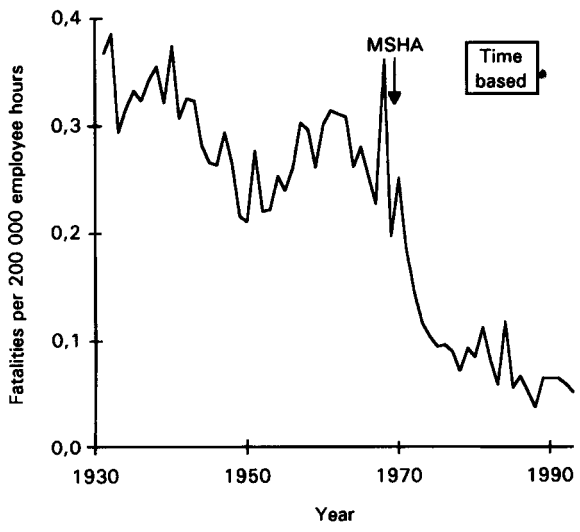

Figure 7—Historical record of fatalities in US underground coal mines, based on employee hours worked (MSHA = Mine Safety and Health Act 1969)

Reflecting on these data and observations, it is clear that US underground coal-mining productivity was affected by a combination of factors. While the most important of them have already been considered here, the possible role of other factors must also be recognized, including the many complex forces at work in the energy field in the 1970s. Nevertheless, in regard to the effect of safety legislation, there can be no doubt that these data and observations signal a warning that legislation can impact very negatively on productivity, and thus also on the viability of mining.

However, in terms of the arguments presented here, it must also be recognized that the impact of safety efforts on productivity, such as that discussed earlier, may be regarded as a *justified, though unfortunate, consequence* of measures considered necessary to reduce the residual safety risk in the US coal-mining industry to an acceptable level[13]. Indeed, consideration of the safety data presented in Figures 6 to 9 provides grounds for such an argument. Nevertheless, the data already given clearly expose the need for the balance between safety cost in its broadest sense and safety benefit to be explicitly taken into account in the quest for improved safety performance.

Impact of regulations on safety performance

Having recognized the real potential for some safety regulations to have a large negative impact on productivity, it is important from an examination of safety records to identify the safety benefits of such regulation. To this end, data from the US and UK[22,23] coal-mining industries are presented in Figures 6 to 9.

Consideration of these figures leads to the following points.

- Over the sixty-year period shown, based on fatality rates, there have been dramatic improvements in mine safety.
- Although time-based safety data give a direct indication of personal risk, they may be misleading when used as an indication of improved mine safety. Although Figure 6 shows that the tonnage-based fatality rate continued to improve following the introduction of the 1969 Safety and Health Act, unlike Figure 7 it does not support the contention[8,13] that the 1969 Act, *per se,* brought about a dramatic improvement in safety.
- Safety performance data can thus give rise to significantly different conclusions, depending on whether they are related to tonnage produced or employee hours worked. The International Labour Organisation has recently pointed out the advantage of using tonnage-based accident statistics, particularly for international comparisons[1].

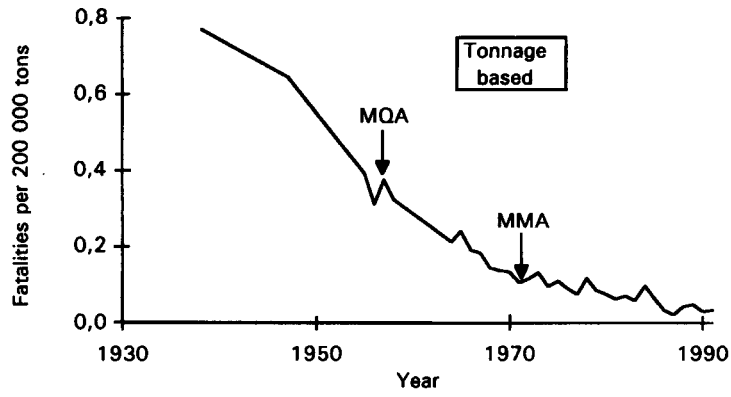

Figure 8—Historical record of fatalities in UK coal mines, based on tons produced. (MQA = Mines and Quarries Act, MMA = Mines Management Act)

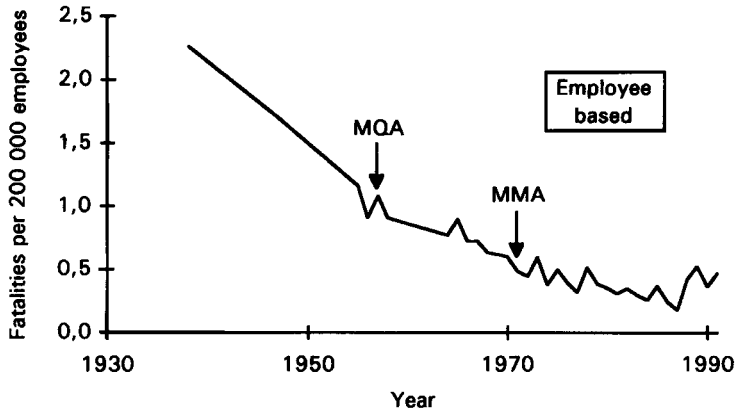

Figure 9—Historical record of fatalities in UK coal mines, based on number of employees (MQA = Mines and Quarries Act, MMA = Mines Management Act)

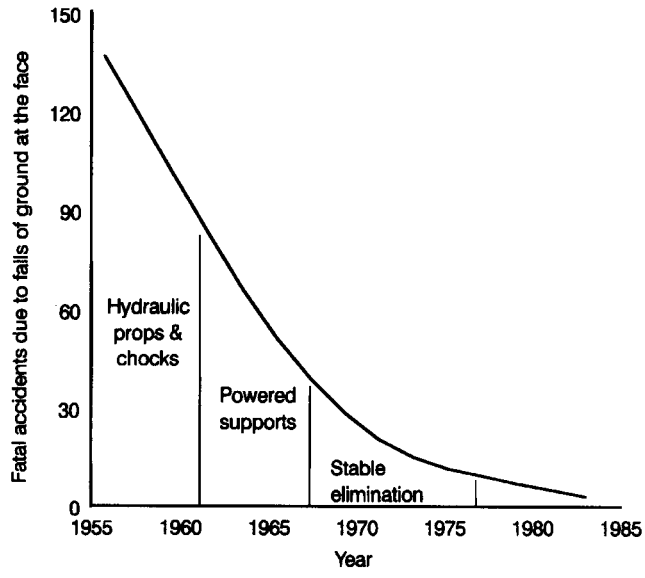

Figure 10—Influence of technological advances on safety in UK coal mines (after Pugh[25])

- The long-term trend towards improved safety, when based on tonnage produced, does not appear to be tightly related to safety legislation. This is shown in Figures 6 and 8. The linkage between safety legislation and safety performance appears therefore to be overlaid with other, rather more significant factors.
- Although improvements in safety and productivity often occur together[24], the data presented in Figures 3 and 6 convincingly demonstrate that this *cannot be assumed.*

In reflecting on the above observations, it is appropriate for one to consider the argument that improvements in safety are primarily due to the steady implementation of improved mining equipment, methods, and technology[8,25]. In advancing this argument, Pugh[25] pointed out that the introduction of hydraulic props and chocks, and ultimately fully mechanized self-advancing hydraulic support systems, was associated with a dramatic reduction in fatal fall-of-ground accidents in UK coal mines, from 140 per year in 1955 to 3 per year in 1983. This is shown in Figure 10. Published data[26-29] reflecting experience in South African gold mines provides strong support for this argument. While recognizing the inevitable existence of other contributing factors, these studies reveal the following.

- Steady growth in the use of hydraulic props in South African gold mines was associated with a marked reduction in fall-of-ground reportable accidents, from 13,4 per thousand employees in 1976 to 7,7 in 1984[27].
- Following a series of rockburst fatalities at a deep-level gold mine, the design and use of stabilizing pillars brought about a sharp reduction in fatalities[28].
- The introduction of trackless mechanized-mining methods on a gold mine suited to such mining was associated with a marked improvement in safety. In the five years prior to trackless mining, the average fatality and reportable accident rates were 0,8 and 18 per thousand employees, respectively. Following a two-year introductory period, the average rates for the next five-year period were as low as 0,3 and 5, respectively[29].
- The introduction of extensive mine-cooling systems on hot deep-level gold mines has produced significant reductions in human heat-stress levels; in a case study, these reductions in heat stress were associated with a very significant improvement in safety. A reduction in the average face wet-bulb temperature from approximately 30°C in 1978 to 28,5°C in 1982 was associated with a reduction in reportable accidents per thousand employees from 42 to 20 over the same period[26].

Acknowledgements

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In his review of the UK's experience, Davies[30] recognized that significant safety benefits were associated with the introduction of improved technology. However, he also highlighted the important positive role that legislation can play. The data presented earlier suggest strongly that one of the major roles of safety legislation should be that of enabling the most appropriate technology to be adopted in any given set of mining circumstances. Regarding other important roles, more recent data and assessments of the factors associated with accidents[24,31] indicate that from 50 to 85 per cent of all mining injuries are due, in large part, to human error. This finding is not surprising, since in such studies the selection of mining method or equipment would have already been made. However, the findings do indicate that appropriate attention must also be focused on human factors. On this point, recent research[24] indicates that the primary causes of human error lie outside the individual and are often induced by poorly designed equipment, unpleasant working environments, and ineffective training.

The data and arguments considered thus far make it clear that although many factors affect safety performance, to maximize the effectiveness of safety and health legislation, it should be oriented towards the introduction and use of improved mining methods, equipment, and technology, and that it should foster attitudes and work practices that reduce the incidence of human error. The data and arguments also warn that prescriptive legislation can have significant negative effects. Indeed, in the event that the latter were to compromise the viability of mining, and it has already been shown that this is a real possibility, safety regulations could become negatively linked to the societal risk factors presented in Table I. This possible linkage is explored in the next section of this paper.

Linkage between regulation and societal risks

While it is not usual, in the formulation of occupational safety regulations, to attempt to take account of a possible linkage between regulations and societal risk factors, the data and arguments presented so far trigger further consideration of that linkage. Clearly, if the unintended consequence of regulation is a significant fall in productivity, including a consequential increase in production costs, mines may be forced to close or to take drastic measures to remain profitable. In some situations, such actions could lead to extensive and protracted job loss, and hence to a significant increase in poverty. As shown in Table I, this would, in turn, lead to a commensurate loss of life expectancy.

In most mining sectors, the variation between geological conditions inevitably causes profitability to vary between mines. This would be the case in most coalfields, and it is also true for gold mining in South Africa. Indeed, it is possible to use data from the South African gold-mining industry to illustrate the potential effect of relatively small increases in working cost on job loss. Data for the South African gold-mining industry are presented in Figures 11 and 12.

Figure 11 shows the variation in working costs between South African gold mines in relation to the gold price; it also shows that, even at the present gold price, there are four mines (involving 17 000 jobs) that are in a loss-making situation. In the absence of an improvement in recovery grade or gold price, many of those jobs will in due course be lost. In many respects, that is, of course, the nature of mining.

However, the important point about Figure 11 is that unintended increases in the cost of mining could precipitate significant levels of job loss. This is shown quantitatively in Figure 12, where a 20 per cent increase in working cost is associated with a potential loss of as many as 129 000 jobs[32]. In South Africa, job loss on such a scale would have devastating consequences, extending well beyond the workers directly affected. The consequences of job loss would, of course, not be the same in all situations, and would vary between countries and communities.

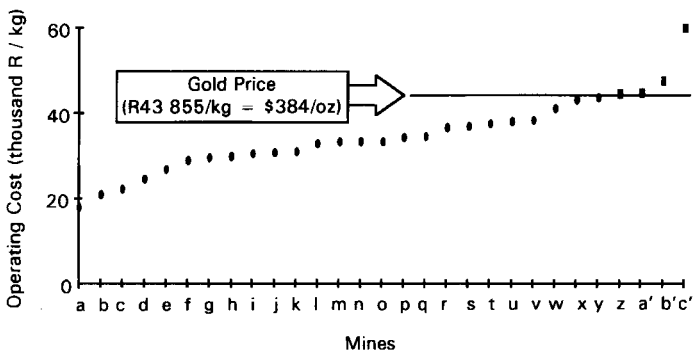

Figure 11—South African gold-mine operating costs, excluding capital expenditure, in relation to the current gold price

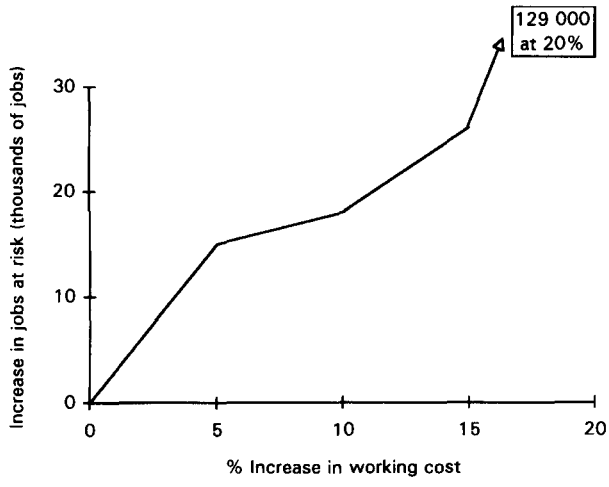

Figure 12—Effect of increased working costs on jobs at risk in South African gold mines

Table II

Gross national product per capita and life expectancy at birth for various countries with a significant interest in mining

Country	GNP/cap 1992 US$	Life expectancy Years
Low income		
Niger	280	46
India	310	61
Nigeria	320	52
Ghana	450	56
Zimbabwe	570	60
Indonesia	670	60
Zambia	?	48
Average	433	55
Lower middle income		
Philippines	770	65
Papua New Guinea	950	56
Peru	950	65
Congo	1 030	51
Ecuador	1 070	67
Colombia	1 330	69
Paraguay	1 380	67
Namibia	1 610	59
Ukraine	1 820	70
Poland	1 910	70
Turkey	1 980	67
Chile	2 730	72
Average	1 461	65
Upper middle income		
South Africa	2 670	63
Malaysia	2 790	71
Mexico	3 470	70
Average	2 977	68
High income		
Australia	17 260	77
United Kingdom	17 790	76
Canada	20 710	78
Finland	21 970	75
France	22 260	77
Germany	23 030	76
USA	23 240	77
Sweden	27 010	78
Average	21 659	77

Key differences between developed and developing countries

While there are many important differences between more-developed and less-developed countries in respect of the consequences of job loss, the key differences are considered to be the general wealth of the nations, and the prevailing levels of unemployment. Using gross national product per capita to characterize wealth, the World Bank[33] has quantified the variation between nations. Also available from the same source are figures of life expectancy at birth for those nations. Table II sets out the gross national product per capita and the life expectancy at birth for a number of countries with a significant interest in mining. It is important to note that these data strongly confirm the link between life expectancy and poverty, the correlation between these two parameters being shown in Figure 13.

Unfortunately, data on unemployment levels are not readily available from the less-developed countries and, even where they are, their reliability must be questioned. For instance, in respect of the available data[34–36], as presented in Table III, it has been estimated that the unemployment figure for South Africa is actually close to 50 per cent as opposed to the 29 per cent figure given in the table.

Based on a consideration of the data presented, the following points are made.

- As well-developed countries generally have much lower levels of unemployment, the scope for re-employment is greater. They can also afford to have arrangements in place to financially support unemployed workers. There are thus significant differences between the more-developed and the less-developed countries in their capacity to cope with workers who have lost their jobs.
- Compared with the well-developed countries, the job loss in developing countries is much more closely associated with poverty, and thus with an increase in loss of life expectancy.

It is also worth noting that the consequences of unemployment are likely to extend beyond the obvious economic effects. In particular, stress levels, mental health, cardiovascular disease, and suicidal tendencies may all be negatively affected[37].

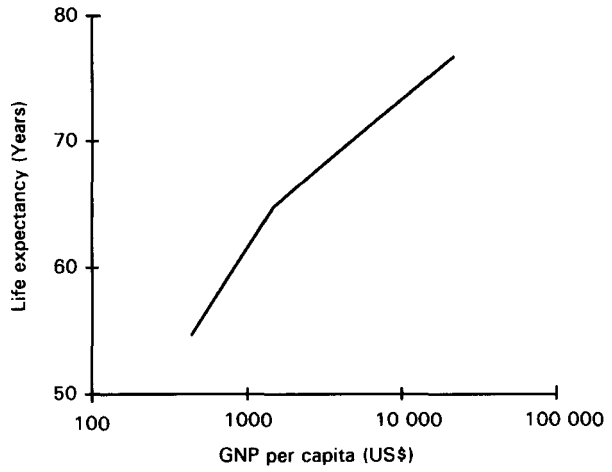

Figure 13—Relationship between life expectancy and gross national product per capita, based on the averaged data presented in Table II

Table III

Unemployment levels in various mining countries

Country	Unemployment per 100	GNP/cap 1992[33], US$
USA	7[35]	23 240
Germany	9[35]	23 030
Canada	11[35]	20 710
Australia	10[35]	17 260
South Africa	29[36]	2 670
Niger	47[34]	280

Note: Limited unemployment data are available for less-developed countries

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The data and arguments presented indicate a need for caution when contemplating the transfer of safety standards from well-developed to less-developed countries. In particular, they warn that, in some situations, improved safety levels experienced by one group of workers could be outweighed by the consequences of unintended job losses experienced by others. This realization carries an important implication for international safety standards and conventions. In particular, it points to the merit of such conventions allowing for the suspension of a well-intended provision if it can be properly demonstrated in terms of risk to life that its enforcement would do more harm than good.

In a much more positive sense, these data and arguments point the way forward in the quest for safer mining. In particular, they warn against prescriptive legislation and highlight the need to engender a positive attitude on mines towards the implementation of more productive *and safer* mining methods, labour practices, and technology. The prime role of legislative and regulatory provisions should thus be to create a framework with incentives for that attitude to flourish on mines, from mine manager to face worker.

Fundamental elements of an effective regulatory approach

In seeking to create a regulatory framework that facilitates the achievement of safe mining conditions and practice, it has become clear that the attitude of the mine manager to safety and health is a key determinant of the extent and effectiveness of the measures taken on a mine to procure the safety and health of workers[31]. It follows therefore that the provisions of legislation and regulations need to exploit, fully and constructively, the extremely powerful and potentially overriding effect that the mine manager can have on the safety and health of the workforce. Equally, it should also be properly recognized that the workers have a crucial role to play but, in seeking to ensure that they are able to play that role, the effectiveness of the mine manager should not be compromised. The relationship between the manager and the workers is thus also of prime importance.

Together with the data, observations, arguments, and conclusions presented earlier, it appears that, in order for a regulatory framework to be effective, it should procure the following:

- use of the most appropriate mining methods, technology, and work practices in any given situation
- use of experience and expert knowledge in deciding the most appropriate mining methods, technology, and work practices to be adopted
- sustained effort to improve safety levels for as long as the incremental effort for further improvements is justified.

The accomplishment of these objectives forms the basis of the regulatory framework outlined below. The framework comprises four key elements.

1. Reasonably practicable measures

Given that the mine manager has a duty to care for the safety and health of the workforce, he should be required by law to take all *reasonably practicable* measures to procure safe and healthy working conditions and practices in his mine. It must be recognized that the total elimination of risk is often not possible, and to require the implementation of measures that are either not reasonable or practicable is in itself unreasonable. More importantly, such an unreasonable requirement would have the effect of evoking a response from managers that would be counter-productive to the interests of safety. Reluctant compliance at minimum cost will not engender a commitment to safety. Instead, it should be recognized that requiring the manager to take all *reasonably practicable* measures is in itself extremely onerous. To this end, and in keeping with recent trends[38], the term *reasonably practicable* should be defined in law as follows:

15. CARR, W. Design for productivity—American viewpoint. *Min. Engr,* vol. 146. 1987. pp. 539–548.
16. SZWILSKI, A.B. Significance and measurement of coal mine productivity. *Mining Science and Technology,* vol. 6. 1988. pp. 221–231.
17. ENERGY INFORMATION ADMINISTRATION. *The US coal industry, 1970–1990: two decades of change.* DOE/EIA- 0559, Washington, DC, 1992.
18. NAVARRO, P. Union bargaining power in the coal industry, 1945–1981. *Ind. Labor Rel. Rev.,* vol. 36,. 1983. pp. 214–229.
19. SUBOLESKI, S.L., and KING, R.H. Estimating technology's impact on underground coal productivity. *Mining Engineering,* vol. 42. 1990. pp. 1159–1164.
20. STEWART, J.M., and HARDMAN, D.R. Contribution of R&D to improved productivity in South African collieries. Presented at the 10th International Conference on Coal Research, Brisbane (Australia), Oct. 1994.
21. ENERGY INFORMATION ADMINISTRATION. *Coal data: a reference.* DOE/EIA-0064(90), Washington, DC, 1991.
22. HEALTH AND SAFETY EXECUTIVE. *Mines annual report.* HSE: Bootle, 1973–1993.
23. BRYAN, A. *The evolution of health and safety in mines.* Letchworth (UK). 1975. p. 97.
24. RANDOLPH, R.F., and CECALA, A.B. The US Bureau of Mines human factors and management research program. *Int. Conf. Reliab. Prod. Control Coal Mines,* 1991. pp. 352–358.
25. PUGH, W.L. Efficiency and safety—the link. *Min. Engr,* vol. 145. 1986. pp. 343–346.
26. SMITH, O. Effects of a cooler underground environment on safety, labour and labour productivity. Presented at the 3rd International Mine Ventilation Congress, Harrogate (UK), Jun. 1984.
27. WAGNER, H. The challenge of deep-level mining in South Africa. *J. S. Afr. Inst. Min. Metall.,* vol. 86. 1986. pp. 377–392.
28. NOBLE, K.R. Stabilising pillars at Blyvooruitzicht gold mine: design and results. *Proc. Mine Safety and Health Congress.* Johannesburg, Chamber of Mines, 1988.

'The term *reasonably practicable* means practicable having regard to

(a) the severity and scope of the hazard or risk concerned;
(b) the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk;
(c) the availability and suitability of means to remove or mitigate that hazard or risk; and
(d) the cost of removing or mitigating that hazard or risk in relation to the benefits deriving therefrom.'

2. Mine-specific codes of practice

Since there is a great variation between mines in terms of geology, mining method, hazards, and risks, the impossibility of fully prescribing safe practices in law, and the merit of arranging for the mine manager to devise and implement *reasonably practicable* measures to procure safe and healthy conditions and work practices, should be evident. Accordingly, the prescriptive requirements of legislation and regulation need to be kept to a minimum in order to give maximum effect to a requirement in law that the mine manager operate his mine in accordance with a mine-generated code of practice. In such a code of practice, it would then be possible for him to take account of the mine's particular circumstances in setting out the various standards and practices necessary to ensure safety. The manager should be required to make that code of practice available to the regulatory authority and workers at the mine, allowing a specified minimum time to elapse before its scheduled date of implementation.

The above two requirements should cause the mine manager, with the participation and assistance of the entire workforce, to fully apply himself to the task of creating safe and healthy working conditions and practices. However, with a view to ensuring that available knowledge and expertise are appropriately taken into account, the following two additional elements are put forward.

3. Guidelines and minimum safety standards

While the extent of prescriptive legislation and regulation should be kept to a minimum, it must be recognized that extensive experience has yielded certain widely applicable safety standards. Where that is the case, it may be appropriate to prescribe their observance in law. However, the more usual case is one in which the use of particular standards or technology should not be prescribed, because differing circumstances need to be taken into account. It is in this context that guidelines to assist with the preparation of mine-specific codes of practice have an important role to play. In addition to setting out the various issues that need to be properly considered in the preparation of a code of practice, such guidelines would also serve the purpose of documenting and ensuring the availability of a directly pertinent body of expert knowledge and experience concerning hazards and risks in mining.

4. Performance-based external audits

Given that the responsibility and authority for devising and implementing safe and healthy working conditions and practices will have been unambiguously assigned to the mine manager, it should be incumbent upon the regulatory authority to monitor and audit the effectiveness of the operational arrangements at each mine. Accordingly, each mine should be required to report accidents and environmental conditions to the regulatory authority on a routine basis. Recognizing the criteria for various categories of accident or environmental condition, with criteria being appropriately established for each mine, the regulatory authority would be empowered to require the mine to undergo an external audit, at the mine's expense, when those criteria have not been met. The establishment of the criteria would be based on the past safety performance of the mine and, in recognition that the ultimate objective is the elimination of all accidents, they should include an agreed annual improvement. In reaching that agreement, it would be important to explicitly take into account the need to strike a balance between *safety effort* and *residual safety risk.* Although there are many ways of setting up such a performance-based auditing arrangement, it is appropriate to note the following essential points that need to be taken into account.

- Mines differ widely, some mines being inherently more hazardous than others.
- Inherently safe mines with relatively good safety records may have considerable scope for improvement, and may warrant being audited with a view to achieving attainable improvements.

29. SCOTT-RUSSELL, H. A survival strategy towards mining in the year 2000. *J. S. Afr. Inst. Min. Metall.*, vol. 93. 1993. pp. 237–251.
30. DAVIES, A.W. Influences on health and safety in mining in the next decade. *Min. Engr*, vol. 150. 1990. pp. 85–89.
31. ODENDAAL, E.P.S. The human factor in safety. Presented at the Mine Safety and Health Congress, Johannesburg, Oct./Nov. 1991.
32. CHAMBER OF MINES OF SOUTH AFRICA. *Assessment of the impact of increases of five, ten, fifteen, and twenty per cent in working costs on pay-limits, and hence on economically recoverable gold ore reserves in South Africa.* Johannesburg, COM, 1994.
33. WORLD BANK. *World development report.* Oxford, 1994. pp. 162–163.
34. INTERNATIONAL LABOUR OFFICE. *Year book of labour statistics.* 51st ed. Geneva, ILO, 1992. p. 600.
35. INTERNATIONAL LABOUR OFFICE. *Bulletin of Labour Statistics,* no. 3. 1994. pp. 46, 49, 59, 68.
36. SOUTH AFRICAN DEPARTMENT OF LABOUR. *Labour Focus,* vol. 2, no. 9. 1994. p.1.
37. MARSHALL, R. Health and unemployment. Presented at the 111th Annual Meeting of the American Public Health Association, Dallas (USA), Nov. 1983.
38. *South African Occupational Health and Safety Act,* 1993.

- As problem areas require focused attention, the criteria for audits, and the audits themselves, should be appropriately differentiated.
- The criteria that trigger an audit should be regarded as the minimum required safety performance. They therefore need to be mine-specific and realistic, while at the same time serving as a sound basis for striking a balance between safety effort and residual safety risk. They should be reviewed periodically in the light of experience and with a view to bringing about necessary improvements.
- The external audit should be conducted either by the regulatory authority or by a competent external agency.
- Following an audit, the mine manager should be required by law to appropriately revise and make available, as before, the codes of practice for the mine.

The primary merit of the above framework is that it will both *allow* and *cause* the most appropriate and effective safety measures to be implemented on each mine, in accordance with the needs of the mine. The system has the potential to bring about real improvements in mine safety performance. In particular, it would allow realistic safety targets to be set for mines individually, and thus for the industry as a whole. Furthermore, through the audit system, it would ensure that appropriate measures are taken to achieve the various safety targets.

Conclusions

Against the background provided by the data and arguments presented in this paper, the following conclusions are drawn.

- Well-intended safety legislation and regulations can have unintended effects such as reduced productivity and increased working costs, and they therefore have the potential to cause job loss.
- The significant differences between developed and less-developed countries could result in a well-intended transfer of safety and health standards from the former to the latter to result in more harm than good.
- International safety conventions should allow for the suspension of specific provisions in a particular country in which it can be properly demonstrated that enforcement would, in terms of risk to life, do more harm than good.
- Key factors in achieving improved safety in mines are the use of the safest mining methods, work practices, and technology that are *reasonably practicable,* and the creation of an attitude and approach in the mine manager and his staff that are conducive to safe performance.
- Safety legislation and regulation need to serve as a facilitative framework for the creation, by the mine manager and his workforce, of safe and healthy working conditions and practices in mines. ◆

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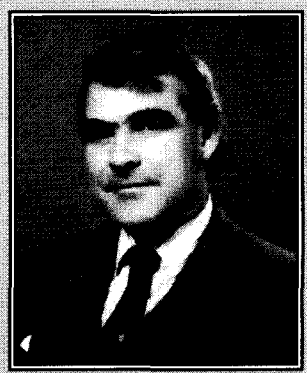

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