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Trends in Major Occupational Injuries in Different Industrial Divisions in Taiwan during 1983–1993

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Abstract: Trends in Major Occupational Injuries in Different Industrial Divisions in Taiwan during 1983–1993: Yu-Chen CHANG, *et al.* Department of Family Medicine, Tainan Municipal Hospital—Objectives: The purpose of this study was to examine the time trend in occupational injuries in main industrial divisions in Taiwan from 1983 through 1993 with newly developed quantification methods. Methods: Data concerning deaths and permanent disabilities caused by occupational injuries were retrieved from the computer files of Taiwan's Labor Insurance Bureau and statistical analyses were performed by using the indices of the cumulative injury rate for from 15 to 64 years of age (CIR_{15-64}), modified severity index (MSI), proportion of potential workdays lost (PPWDL) and foregone earnings lost. Results: Mining and quarrying was the most risky industry, when expressed in both frequency and severity. The mean rates over the 11 year period were as follows: disabling frequency rate, 24.0; incidence rate, 0.012 (yr^{-1}); CIR_{15-64}, 0.491; disabling severity rate, 7,591.7; modified severity index, 22.5; and the PPWDL, 3.72 (10^{-3}). In terms of frequency, incidence rate and CIR_{15-64}, manufacturing was second and agriculture third. With regard to severity, MSI and PPWDL, agriculture ranked second and construction ranked third. The overall trend in occupational injuries in Taiwan has steadily improved in the past decade. All indicators of human capital loss in 1993 were nearly down to one third of those reported in 1983. The estimated potential salary lost in all industries of 1993 was 584.6 million US dollars. Conclusions: Mining and quarrying was still ranked the most risky industry during 1983–93. We have demonstrated that CIR_{15-64}, MSI, PPWDL and foregone earnings lost supplemented disabling frequency and severity rates in the aspect of human capital loss. There was a consistently improved trend in occupational injuries in Taiwan during 1983–93.
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Key words: Occupational injury, Cumulative injury rate, Severity index, Proportion of potential workdays lost, Human capital

Accidents have been the third leading cause of deaths in Taiwan since 1976[1]. There have been more than 1,500 cases of occupation-related deaths and more than 5,000 cases of permanent disabilities in recent years[2]. Among the figures of deaths and disabilities are the precious lives lost and the functionally disabled individuals that have emerged, which has brought enormous grief and economic burden to the injured victims, as well as to their families and Taiwanese society as a whole[3, 4].

Efforts made to prevent the occupational injuries are usually monitored by valid indicators. The disabling frequency and severity rates have been used worldwide since 1967 in order to quantify how many occupation-related injuries occur and how serious they are to a firm[5], but when extending these indicators from the level of the firm to that of an industry or even a country, these two indicators have some drawbacks which limit their application. For example, the disabling frequency rate cannot be interpreted as the lifetime risk of an occupational injury for a worker, nor does it take into account the difference in age distribution among industrial divisions. The disabling severity rate incorporates the fixed numbers of days disabled charged to a particular condition of disability from a standard table, which does not consider the actual loss in workdays for the disability, nor can it be used to crudely estimate the economic cost of occupational injuries. Moreover, companies with less than 30

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employees are not legally required to report their occupational injuries in Taiwan. Even if the firm size might not necessarily correlated inversely with the frequency and/or severity of occupational injuries[6]. The statistics accumulated by governmental agencies in Taiwan may underestimate the real problems of occupational injuries because large companies generally can afford to invest more on occupational safety and health, which usually presents us with a less frequent and severe figure for occupational injuries. We have therefore proposed a cumulative injury rate from 15 to 64 years of age (CIR_{15-64}), severity index, proportion of potential workdays lost (PPWDL) and potential salary lost as complementary indicators to show the loss in human capital[7]. The $CIR_{15\ 64}$ is supposed to be an alternative index to the disabling frequency rate both for its inherent adjustments of uneven age distribution for assessing a worker's lifetime risk of acquiring occupational injury in a specific industry[8 10]. The concept of potential workdays lost involves the estimation of the potential workdays a worker would lose if he died or was on sick leave due to occupational injuries. The total potential workdays lost can be directly interpreted as a quantitative loss of human resources to society and converted into a monetary value. The severity index, PPWDL and potential salary lost were developed to quantify the severity aspect of occupational injury of specific industries. They were also used as indicators supplemental to the disabling severity rate, introducing the concept of standardization in epidemiology and the concept of human capital in economics[7,11]. In this study, we use these new indicators to analyze and to compare the time trend in occupational injuries for different industrial sectors of Taiwan for comparison during 1983–93.

Subjects and Methods

Workers in every industrial company which employs more than five persons have been required to register with Taiwan's Labor Insurance Bureau since 1951. All subjects suffering from occupational injuries, either death or permanent disabilities, were compensated and thus further data registered, for example injury date, kind of injury, grade of permanent disability (15 grades are used in Taiwan) and personal industrial code number, etc. These data from paper documents have been transformed into computer files since 1983. We have retrieved all of the computerized data files from 1983–93 from the Labor Insurance Bureau of Taiwan Provincial Government for this analysis. The data regarding population at risk came from the annual reports of statistical data for the Taiwan-Fukein area Labor Insurance[2]. These data also include the workers' mean salary for each industrial division.

The methods used to quantify the occupational injuries came from two aspects of measurements, the frequency and the severity. The frequency indicators included the incidence rate and CIR_{15-64}. The severity indicators included the severity index, PPWDL and potential salary lost. Details of advantages and limitations were given in our previous report[7], but there are modifications of the indices should be taken care of here. In our proposed model of potential workdays lost, we derived the figure for lost workdays based on three main categories of outcomes of occupational injuries, cases of premature death, permanent disability and temporary dysfunction. But the category of tempopary dysfunction was omitted from this study because the computer files from Labor Insurance contained only cases of deaths and permanent disabilities. In addition, the severity index was also modified by substituting the "total number of person-hours worked" for "total number of person-years worked" in the denominator while the numerator remained the same (potential workdays lost), because of the limitation of data available from the computer file. This quotient we named the modified severity index (MSI) to distinguish it from the original severity index.

The cost of an occupational injury usually included the direct and indirect costs[3]. The potential salary lost, or foregone earnings, was estimated from the potential workdays lost which were multiplied with age, gender and industry specific daily salary[2]. From an economic point of view, such approaches are practical supplements which can be directly used to count the human capital cost of occupational injuries, and they are usually considered as the lower bound of the costs estimated from the method of willingness-to-pay[7, 12].

The disabling frequency and severity rates for nine main industrial divisions during 1983–93 were taken directly from the annually published data from the Council of Labor Affairs of Taiwan[1], which included not only occupational mortality, total and partial permanent disabilities, but also temporary disability compiled from the registration reports of companies with more than 30 employees. We compared the results for disabling frequency and severity rates from the publishing document[1] with the indicators, $CIR_{15\ 64}$, MSI, PPWDL and potential salary lost which were calculated from the computer file. Although the sources of data differed from each other, it is interesting to compare the trend in these indicators, and readers should

look with caution at the tables and figures because of the difference between data sources.

According to the standard classifications of industry and occupation in Taiwan, there are nine main industrial divisions[13], which is the same as the definition from the International Labor Office (ILO). For convenience in reading, we used a typical industry to represent its category in this article. The representations here are: agriculture, for agriculture, forestry, hunting and fishing industries; mining, for mining and quarrying; public utilities, for water, electricity and gas services; transportation, for transport, storage and communication; financing services, for financing, insurance, real estate and business services; social services, for public administration, social and personal services.

Results

There were a total of 70,052 cases of death and permanent disabilities due to occupational injuries recorded from 1983 through 1993. On average, there were 1,403 (standard deviation 228) annual deaths and 4,966 (standard deviation 669) annual permanent disabilities. The ratio of permanent disability to death was greater than 3.5 annually. With regard to the actual number of injuries, the manufacturing industry ranked the most frequent either in deaths or permanent disabilities and such figures were much higher than all the other industries. This industry was followed by agriculture, transportation and construction for occupational mortality and by construction, mining and commerce for permanent occupational disability, as summarized in Table 1. The average age of workers acquiring such a severe occupational injury was 36.3 years of age (standard deviation 12.8). Severe occupational injuries in mining were suffered an average age of nearly 50 years, which was exceptionally older than all the other industries. On the other hand, the average ages of workers with occupational injuries in manufacturing and commerce industries were 34.1 and 33.7 years respectively, which were relatively young. Manufacturing industries recruited a large proportion of the total working population in Taiwan, 2,664 ($\times 10^3$), whereas the mining and public utilities had the smallest working populations, 20,100 and 34,000 on average, repectively.

Table 2 shows the annual mean values for various indicators of occupational injuries by different industrial divisions during the past 11 years (1983–1993). The annual incidence rate of occupational mortality or permanent disability was highest in the mining industry, which was 11.97×10^{-3} yr^{-1} and followed by manufacturing 1.67×10^{-3} yr^{-1}. $CIR_{15\text{-}64}$'s had a similar distribution with an incidence rate over different industries of which the highest was in the mining industry with a lifetime risk of 0.49. This means that if a worker worked in such an industry throughout his lifetime (15 to 64 years of age), then the risk of acquiring an occupational injury which resulted in death or permanent disability would be 49%. Manufacturing and agriculture were two industries with a $CIR_{15\text{-}64}$ near ten percent. Financing services, social services and commerce were the three least dangerous industrial divisions, with a lifetime risk of less than two percent. As to the severity of occupational injuries, both the agriculture and construction industries had a potential workdays lost (PWDL) of 1.85×10^6 which was ranked second, next to the highest 8.47×10^6 of the manufacturing industry. But the working population at risk in each industry varied to a great extent (Table 1), so that the potential affordable workdays (PAWD) varied to a great extent accordingly. Thus, while these numbers served as denominators, the ranks of proportion of potential workdays lost (PPWDL) differ from those obtained by comparing the incidence rate and $CIR_{15\text{-}64}$. Although the ranking for MSI and PPWDL was exactly the same, the

Table 1. Mean annual age, number of workers suffering occupational death and permanent disabilities and working populations in nine main industrial divisions from 1983 through 1993 in Taiwan

Industrial division	Age	Deaths	Permanent disabilities	Working population (10^3)
Agriculture	40.2 (12.3)	217.1 (63.9)	142.3 (36.9)	234.5 (30.4)
Mining	49.5 (8.0)	54.7 (88.1)	218.5 (161.6)	20.1 (6.2)
Manufacturing	34.1 (12.5)	495.7 (70.8)	3,830.8 (530.6)	2,664.0 (465.8)
Public utilities	40.1 (11.3)	14.4 (4.2)	12.5 (5.5)	34.0 (1.4)
Construction	39.1 (11.6)	189.9 (70.6)	279.1 (82.1)	469.1 (232.7)
Commerce	33.7 (12.0)	93.9 (42.9)	189.3 (87.0)	822.2 (418.2)
Transportation	42.2 (11.1)	202.3 (37.2)	178.9 (27.7)	460.1 (93.6)
Financing services	36.6 (11.9)	29.0 (12.5)	17.0 (7.1)	282.0 (156.1)
Social services	43.1 (12.7)	105.2 (18.7)	96.9 (21.2)	798.5 (316.7)

Standard deviations are shown in parentheses.

Table 2. Means of different indicators of occupational injuries which resulted in permanent disabilities or death in nine main industrial divisions in Taiwan during 1983–93

Industrial division	No. injuries	DFR	IR(10^{-3})	CIR_{15-64}	DSR	PWDL(10^{6})	PAWD(10^{9})	MSI	PPWDL(10^{-3})
Agriculture	359.50 (95.90)	4.91 (4.01)	1.58 (0.50)	0.081 (0.025)	2,275.55 (2,083.33)	1.85 (0.61)	1.65 (0.20)	8.18 (2.93)	1.16 (0.41)
Mining	273.20 (211.90)	24.02 (13.64)	11.97 (7.57)	0.491 (0.293)	7,591.73 (11,013.38)	0.52 (0.61)	0.12 (0.03)	22.50 (21.44)	3.72 (3.71)
Manufacturing	4,326.50 (582.60)	3.25 (0.26)	1.67 (0.37)	0.092 (0.021)	386.09 (76.60)	8.47 (1.27)	24.98 (3.31)	3.29 (0.80)	0.34 (0.06)
Public utilities	27.00 (7.40)	1.19 (0.35)	0.79 (0.21)	0.048 (0.019)	690.45 (236.93)	0.12 (0.04)	0.27 (0.02)	3.63 (1.12)	0.45 (0.13)
Construction	469.00 (148.60)	1.62 (0.63)	1.11 (0.26)	0.060 (0.014)	1,362.70 (1,386.94)	1.85 (0.62)	3.82 (1.90)	4.42 (1.20)	0.54 (0.14)
Commerce	283.20 (127.10)	- -	0.35 (0.04)	0.019 (0.003)	- -	1.11 (0.50)	7.70 (3.84)	1.42 (0.27)	0.15 (0.02)
Transportation	381.20 (56.30)	6.36 (1.95)	0.87 (0.23)	0.049 (0.014)	1,500.82 (727.09)	1.67 (0.30)	3.66 (0.67)	3.79 (1.03)	0.47 (0.12)
Financing services	46.10 (18.90)	- -	0.18 (0.04)	0.013 (0.003)	- -	0.27 (0.13)	2.73 (1.51)	1.03 (0.24)	0.10 (0.02)
Social services	202.10 (39.10)	0.95 (1.02)	0.28 (0.08)	0.018 (0.005)	271.89 (432.47)	0.77 (0.15)	6.87 (2.73)	1.07 (0.31)	0.12 (0.03)

DFR : disabling frequency rate, IR : incidence rate, CIR_{15-64} : cumulative injury rate from age 15 to 64, DSR : disabling severity rate, PWDL : potential work days lost, PAWD : potential affordable work days, MSI : modified severity index, PPWDL : proportional of potential work days lost. Standard deviations are shown in parentheses.

Table 3. Temporal trend in various indicators of occupational injuries which resulted in permanent disabilities or death in Taiwan during 1983–93

Year	No. injuries	DFR	IR(10^{-3})	CIR_{15-64}	DSR	PWDL(10^{6})	PAWD(10^{9})	MSI	PPWDL(10^{-3})	GNP
1983	5,403	4.57	1.625	0.092	620	14.32	31.41	4.30	0.45	2,940
1984	6,404	4.25	1.733	0.098	1,193	16.99	34.61	4.60	0.49	3,310
1985	6,047	3.91	1.493	0.085	627	14.94	37.40	3.69	0.39	3,515
1986	6,927	3.80	1.470	0.082	747	17.04	43.48	3.61	0.39	4,089
1987	7,456	3.63	1.401	0.078	607	18.66	48.57	3.50	0.38	4,616
1988	7,440	3.65	1.244	0.070	420	19.87	53.91	3.32	0.36	5,048
1989	7,012	3.32	1.070	0.059	420	19.48	58.48	2.97	0.33	5,631
1990	6,244	3.27	0.911	0.050	423	18.32	60.27	2.67	0.30	6,166
1991	6,342	3.26	0.870	0.048	437	16.91	63.42	2.32	0.26	6,887
1992	5,996	2.95	0.777	0.042	385	15.12	66.49	1.96	0.22	7,604
1993	4,781	2.86	0.585	0.032	384	11.80	72.10	1.44	0.16	8,345

GNPs are also shown in the last column for reference (US $).

Table 4. Estimated potential salary lost due to occupational injuries resulting in permanent disabilities and death from 1983 through 1993 in Taiwan with various discount rates (r)

Year	r=0.04	r=0.06	r=0.08	r=0.10	Working population
1983	1007.61	709.52	526.16	407.74	3,112,953
1984	1179.27	835.35	622.68	484.63	3,495,478
1985	1040.01	733.26	544.43	422.37	3,845,701
1986	1201.58	843.87	624.03	482.31	4,364,316
1987	1311.78	920.89	680.45	525.36	5,012,722
1988	1396.33	980.63	724.80	559.72	5,630,981
1989	1359.82	962.20	715.18	554.52	6,265,302
1990	1271.08	902.11	672.14	522.10	6,662,442
1991	1182.29	843.56	631.38	492.29	7,021,954
1992	1044.48	744.54	556.62	433.46	7,486,387
1993	822.36	584.63	436.23	339.28	8,715,284

(Unit : Million US $) The monetary values are already adjiusted for inflation to that of 1993.

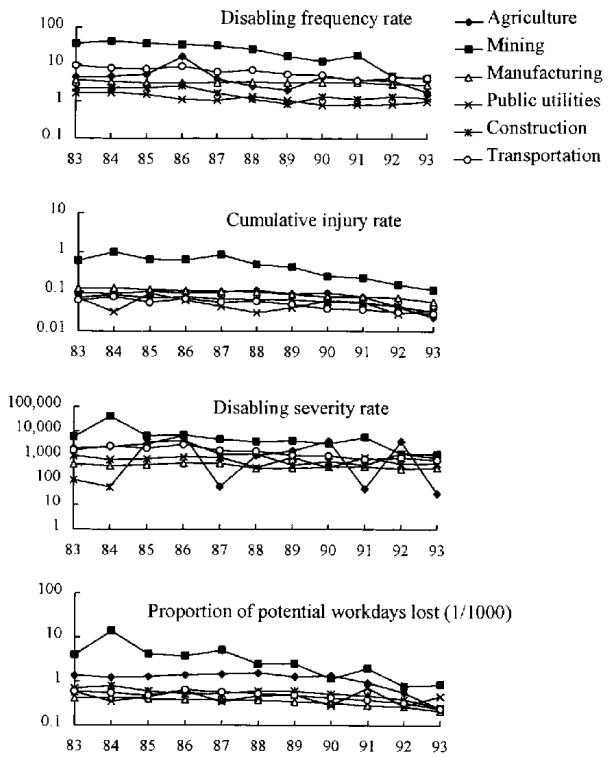

Fig. Temporal trend in disabling frequency rate, cumulative injury rate, disabling severity rate, and propotion of potential workdays lost in six main industries in Taiwan during 1983–93. The Y axis is on a logarithmic scale.

fluctuations among industrial divisions showed less diversity in MSI than in PPWDL. The top four industries in either MSI or PPWDL were mining, agriculture, construction and transportation, which indicated that mining in Taiwan was still the most dangerous trade and suffered the most severe workday loss.

We have summarized all the workers in Taiwan to examine the trend in annual change from 1983 to 1993 (Table 3). The incidence rate, CIR_{15-64}, MSI and PPWDL have declined steadily since 1985. In contrast, the gross national product (GNP) has grown steadily annually. All indicators of human capital lost in 1993 were nearly down to one third of those reported in 1983. The estimation of potential salary lost or foregone earnings of injured workers in 1993 was 339.28 million US dollars with an annual discount rate of 0.10, and 822.36 million with a discount rate of 0.04 (Table 4). With either discount rate, the trend in the potential salary loss in the last decade was pictured as a slightly convex curve, with the focal point of the curve being around 1986–90.

To examine the time trend in CIR_{15-64} MSI, PPWDL and potential salary loss (Fig.), we have found a steady improvement in occupational injuries with regard to both frequency and severity throughout the past decade in Taiwan. The ranking and relationship of each industrial division in occupational injuries were clearer in both figures. As to frequency, the line of public utilities even crossed the line of construction in the CIR_{15-64} graph, but such evidence did not appear in the incidence rate graph. As to severity, the almost crossed lines for manufacturing and agriculture industries are seen in the MSI graph, but the PPWDL line for agriculture was apparently separated from and consistently positioned higher than that for the manufacturing industry. This suggested that the social impact of occupationl mortality and permanent disability was more clearly reflected in the PPWDL curve because it has taken account of the different age distributions in different industrial sectors. Similar findings were also disclosed in the comparison among manufacturing, construction and public utility industries.

Discussion

Although the CIR_{15-64}, MSI, PPWDL and potential salary loss calculated in this study may more appropriately quantify the lifetime risk and human capital loss of occupational injuries than those of the disabling frequency rate and severity rate[7], the computerized data we obtained did not include the cases of temporary dysfunction. Our analysis may therefore inevitably underestimate the true impact of occupational injuries to a certain extent. Nonetheless, since our study contained all cases of permanent disability and death, it can be viewed as including all cases of serious occuptional injuries and thus still reflects the general time trend of these indicators for severe injuries in different industrial sectors. Moreover, the national data avoid age strata compiled from small numbers, which also made the CIR_{15-64}'s more robust and interpretable as a lifetime risk of serious occupational injuries.

According to Table 3 and the Figure, all $CIR_{15\ 64}$'s, MSI's and PPWDL's have consistently improved during 1983–93, showing that both the frequency and severity of serious occupational injuries have decreased by a factor of three, but we still need to consider other possible alternative explanations before reaching the conclusion that occupational safety in Taiwan has really improved. Mandatory workmen's compensation insurance were expanded step by step to cover commerce, financial and social service industries and smaller companies which employed more than two employees during 1983–93. The expansion was thought to have a diluting effect on the indicator of occupational injuries[7], because the newly included industries were generally less dangerous than manufacturing and/or con-

struction industries, which were covered first. Nevertheless, since the absolute incidences of occupational mortality and disability dropped from 1,180 and 4,223 in 1983 down to 992 and 3,789 in 1993, respectively, and the total number of workers covered increased from 3.11 million and 8.72 million, as shown in Table 4, the possibility of a diluting effect can largely be ruled out. Moreover, all indices of frequency and severity have showed a consistent time trend toward improvement after being stratified for different industrial sectors, which further argues strongly against the diluting effect. Another complication was the introduction of foreign workers during the last few decades, because they might have been assigned to more hazardous jobs and thus masked the true effect. But our data have already included all foreign workers who were legally employed. Thus, the possibility of simple transfer of dangerous jobs to foreign workers could also not explain the improvement. So we concluded that there had been a significant improvement in occupational safety in the work environment of Taiwan during 1983–93. Such an improvement may be the result of a combination of different factors: the enactment and enforcement of Standard Labor Law in 1986, which has provided a legal basis for an independent labor union and has increased the number of inspectors and frequency and scope of factory inspection; the general improvement of workers' education and living standards, which has made safety and health a more focused concern among workers; the regulation that employers should pay at least a 30 percent share in workmen's compensation has created an economic incentive, but more studies, including international comparison, need to be done in the future to clarify the reasons.

The mining industry had a CIR_{15-64} of 0.49 (Table 2), which was top among the various industries. It indicated that a worker had an approximately 50% chance of incurring a major occupational injury either death or permanent disability, during his lifetime. The reason for such a high mean CIR_{15-64} is probably due to the unsafe working environment in the 1980s, when mining workers were usually exposed to explosions and the collapse of mining tunnels, causing major casualties in this industry in Taiwan. In addition, the number of workers in the mining industry was extremely small after stratification by age, e. g., several hundreds of workers in a specific stratum, which made the estimation of $CIR_{15\ 64}$ relatively unstable. But the steady decline in the CIR_{15-64} figure (Fig.) shows that occupational safety has been improved during the past decade. Nevertheless, such a dangerous trade still deserves more effort and strong intervention procedures from both the government and the public. The manufacturing, agriculture and construction industries had a CIR_{15-64} figure between 0.05 and 0.1. Since all these injuries were serious, involving at least partial permanent disability, we recommend that more should be done concerning occupational safety to improve conditions.

The determination of potential workdays lost required a standardized procedure to assess exactly how many workdays were lost for every specific type of permanent disability. Such a procedure and the resulting schedule have not yet been developed, and we simply applied the currently existing classification of 15 grades of disability from the workmen's compensation system regulated in Taiwan[14], which was proven to correlate quite well with the monthly income loss[15]. Further standardization of such figures will be needed for future comparison of MSIs, PPWDLs and potential salary loss in various countries. Based on the detailed schedule of potential workdays lost, we have taken the age factor into account and can directly estimate the human capital cost of occupational injuries by adopting the MSI and PPWDL, rather than the disabling severity rate. In our study, we have shown that the disabling severity rates for industries in agriculture fluctuated to a great extent when it was compared with the mining, manufacturing, construction and public utilities as in the Figure. The MSI straightened the above trend to some extent after considering the age factor in the numerators, while the PPWDL more clearly delineated the temporal trend of these industries by also taking account of the age factor in the denominators (Fig.). For example, the manufacturing industry ranked second highest in the MSI graph, but it dropped to fifth in the PPWDL graph, even lower than that of the public utilities. The main reason was that the mean age of the population at risk in manufacturing industries was 33.5 years, and standard deviation 2.2 years, which was younger than that of other industries (average age for all industries 37.1 years, standard deviation 4.0 years) and resulting in a larger potential of affordable workdays in the manufacturing industry.

Foregone earnings, or potential salary lost, is considered to be a major part of the cost of occupational injuries[16], and regarded as a lower bound[12] of cost estimated by the willingness-to-pay concept. It is more direct for employers to see the impact of occupational injuries with a monetary value. We took the average growth in the GNP between 1981 and 1991 in Taiwan as a substitute for the growth in labor productivity. The smaller the discount

rate, the larger the estimated figure derived (Table 4). When the discount rate was taken as 0.06, the estimation of potential salary lost was 585 million US dollars in 1993. Such a huge resource could be saved and utilized for more positive social construction each year instead of burdening the injured individual, or his family, or all of society by appropriate reduction of occupational injuries.

The incidence rate, CIR_{15-64}, MSI, PPWDL and foregone earnings estimation described the status of occupational injuries from 1983 through 1993 in Taiwan including the nine main industrial divisions covered by this study. We concluded that although steady improvement over the past decade in each indicator showed that an effort had been made by the government and the public to reduce accidents, the mining, agriculture and construction industries still need to have more effective action taken to attain to appropriate injury control. This study explored the main industries only. Further studies should focus on an analysis of occupational injuries in more widely classified industries and try to identify possible risk factors in the industries.

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