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Older Workers: Asset or Liability for Your Company? The Case Study of Metal and Non-metal Mines

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Introduction

This study was conducted to analyze the relationships of various demographic metrics associated with fatal accidents in metal and non-metal mines between 2002 and 2006 in the United States of America. Three demographic factors – 1) age of the miner, 2) job experience and 3) the number of employees in the mine were investigated. ANOVA was used to analyze the statistical relationships between these factors and the fatal accidents. The analysis found that workers who were involved in the fatal accidents were more likely to belong to the same **Age** group and **Experience** group – for example, younger workers with the least experience and older workers with the most experience. Most fatalities came from mines with less than 50 employees.

Workers between the ages of 17 and 24 had the highest rate of fatalities per 100,000 workers (47.37 fatalities per 100,000 workers), followed by workers over the age of 55 (32.38 fatalities per 100,000 workers). For the risk index (RI), workers between the ages of 17 and 24 had a RI of 1.92. The RI indicates that workers in this age group had a higher risk of being involved in fatalities than any other age groups. Workers over the age of 55 had the second highest RI (1.33) which also indicates high risk.

The largest class of fatal injuries in metal and non-metal mines was powered haulage, followed by machinery, fall of material, and fall of person. Aging workers and those workers with less than 5 years of experience represented the largest percentage of fatalities involving powered haulage.

1. Introduction

The International Labor Organization (ILO) has estimated that by the year 2025, individuals above the age of 55 will represent 32% of the total population in Europe, 30% in North America, 21% in Asia and 17% in Latin America. According to the National Traumatic Occupational Fatalities data from 1980 to 1991, workers over the age of 65 had a fatality rate of 2.6 times that of workers between the age of 16 and 64 (Jenkins et al., 1993). The highest fatality rates in all age groups were reported in mining (62.7 per 100,000 workers), followed by agriculture (52.6 per 100,000 workers) and construction (40.2 per 100,000 workers) (Kisner and Pratt, 1997). It is therefore imperative to study and understand the relationships between the age demographics and fatality rates especially in an industry such as mining where the median age is rising. Research linking age and job performance among miners has been done as early as 1928 by Vernon and Bedford (1928).They studied men working in 10 coal mines during 1924 and 1925 who performed similar tasks. They found that the workers between the ages of 30-39 years of age had the lowest rate of fatality and workers over the age of 59 years of age had the highest rate of fatality. Workers below the age of 20 were also found to have a higher rate of fatality than other age groups except for the age group over 59 years old. Older workers were found to have lower non-fatal injury rates, but to need longer recovery time after each accident, and to suffer a higher rate of fatality (Vernon and Bedford, 1928). Given that mining is seeing its median age of workers increasing, this paper will explore whether: 1) Older workers with the least experience will have the highest fatality rates; 2) Workers working in small mines will have the highest fatality rates using data of fatalities in metal and non-metal mines between 2002 and 2006.

2. Defining Aging Workers

Aging and aging workers have been defined differently by various engineers, medical doctors, and psychologists. Ilmarinen (2001) argued that while workers between the ages of 15 and 64 are aging – aging workers should only be used to describe workers who have experienced "major changes in relevant work related functions during the course of work life." Roy Shepard (2000) associated aging with progressive decreases in aerobic power, thermoregulation, reaction speed and acuity of the special senses. Kathleen Kowalski et al. (2005) suggested that the definition of aging workers should be made more situational than chronological. They suggested that numbers alone should not put someone in the category of older workers while Sterns and Miklos (1995) chose a different tract altogether by defining aging as changes that occur in biological, psychological and social functioning through time. They argued that the distinction between older and younger workers rests more frequently on chronological age. Their argument was bolstered by the legal definition in the Age Discrimination in Employment Act (ADEA) which protects workers over the age of 40 from age discrimination (Haight, 2003). The Job Training Partnership Act and Older Americans Act on the other hand defined aging or older workers as those above the age of 55.Even while pointing to these legal definitions used to protect workers based on age, Sterns and Miklos (1995) warned that the study of aging workers should also include both environmental and individual factors of aging and work place. They also argued that age is very poor indicator of a worker's performance level but that an ergonomically designed work place might create fewer hazards to aging workers.

Stagner (1985), on the other hand found that older workers are perceived to be more accident prone and are less motivated. His work brought another definition for aging workers based on psychosocial factors. Aging workers are defined by Stagner (1995) based on social and individual perceptions. Schwab and Heneman (1977) in their study found that aging workers are perceived to be dependable and knowledgeable. Cleveland and Shore (1992) found that workers who perceived themselves to be older than other workers in their work group tend to have more job satisfaction and organizational commitment. These positive and negative psychosocial perceptions might be another factor that can be used to define aging workers.

Juhani Ilmarinen (2001) used workers between the age of 45 or 50 years as the base criterion to define aging workers . Ilmarinen (2001) believed that there is a need for early definition of aging workers for preventative measures. This she said is important because of the low participation rates of workers over the age of 55 in the workplace. Ilmarinen (2001) also used the term metacognition to describe the process of aging. Metacognition is the evaluation of one's own cognitive function and one's attitude towards their own aging which is closely related to their mental capacity. Ilmarinen (2001) found that motivated aging workers can compensate for their loss in cognitive speed and precision with their experience and wisdom that they have accumulated throughout their careers. While aging slows some cognitive functions like the ability to process complex problems, it can enhance other cognitive skills such as ability to reason and ability for better verbal command. Illamarinen (2001) therefore suggested a more creative usage of job experience among aging workers such as tailoring training using new technology to enhance their work lives.

Warr (1994) defined older workers as workers above the age of 40. Warr (1994) compared younger workers and older workers using three sets of attributes – 1) physical abilities; 2) adaptability; and 3) general work effectiveness. He concluded based on his study that physical abilities and adaptability decreased among older workers while general work effectiveness increased among these older workers. Older workers tend to take longer time to process information and therefore will perform poorly on tasks that required rapid cognitive processing.

There are no age cutoffs to describe aging workers in the research literature (Maurer, Wrenn and Weiss, 2003). Ashbaugh and Fay (1987) in their review of 105 papers on aging workers, found that the average chronological age used to describe aging workers was 53.4 years. Sterns and Doverspike (1989) believed that aging cannot be adequately described by using a single definition because aging is a multidimensional process.

Given the complexity of deciding the definition of aging workers – aging workers in this paper will be defined as those above the age of 55. According the U.S. Census Bureau, by 2020 nearly half of all U.S. adults will be over the age of 55 (U.S. Census Bureau, 2002). This will further increase the importance of industrial gerontology and gerontechonology – the discipline to help aging workers to have better work experiences with the latest technology; this term was coined by Graafmans and Brouwers (1989).

2.1 Consequences of Aging

Ilmarinen (2001) studied aging workers using three criteria – physical, mental and social aging process. For the physical capacity criteria, there has been a decline in maximal oxygen consumption (VO_2max) among aging workers in both male and female. This decline is shown to begin at the age of 30 years. The decline is dependent upon the workers' involvement in the aerobic exercise. Workers are allowed to be involved in physical work that does not exceed 50% of their VO_2max. For example, a job demanding workers to be involved in moving and carrying loads will need oxygen consumption of 1.0 l/min. So, the worker should have an average of 2.0 l/min. The decline of VO_2max limit among aging workers means they should be doing less demanding physical jobs and should be involved in regular exercise.

Aging workers are also found to have declining musculoskeletal capacity after the age of 45-50 years. In a ten year period study done by Nygard (1999), maximal isotermic trunk extension and flexion decreased by 40-50%. Nygard (1999) also found that this decline was similar for blue and white collar workers. Ilmarinen suggested based on Nygard's (1999) study that physical load of aging workers should be reduced by 20-25% and regular exercise should be recommended for these workers. He cautioned that individual differences between these aging workers can be huge and that living habits can accelerate or slow down the aging process.

Certain cognitive abilities decline in aging workers while others may improve (Callahan, Kiker, and Kross, 2003). Despite this, brains in aging workers are able to replace the lost neurons and training will increase the brain functions of aging workers to match those brain functions of the younger workers (Begley, 2006). Various other factors can also affect the cognitive abilities of aging workers. These include biological factors (pain, nutrition, disease), psychological factors (stress, depression), and psychosocial factors (education, motivation) (Lowenstein, 2005).

Intelligence can be divided into two – fluid intelligence and crystallized intelligence. Papalia et al. (1996) found that the decline in fluid intelligence in aging people is balanced with the increase in crystallized intelligence. Fluid intelligence is determined by genetic and physiology and tends to decline between the ages of 25 and 75. This intelligence allows us to process new information and apply our own mental abilities without past experience or knowledge (Perlmutter and Hall, 1985). Since fluid intelligence tends to decline with the aging process, aging workers will be at disadvantage compare to younger workers. Crystallized intelligence is affected by culture and prior knowledge. Intelligence on this hand, tends to increase with the aging process

The process of aging is associated with the decline in homeostasis and functional loss (McDonald, 1998). The decline in homeostasis in aging workers means they have reduced capability to maintain their body at normal operation. This means aging workers will have hard time working in extremes of heat and cold because they are incapable of adjusting to the temperature changes compare to younger workers. They also will have hard time working in shift work because their body recovers more slowly from altered sleep and meal patterns. They might take longer time to recover from injury (Hale, 1990; Hansson, DeKoek, Neece and Patterson, 1997).

Physical strengths also decline with age (Warr, 1994; A.A. Sterns, Sterns and Hollis, 1996). Bones become lighter and brittle while lean muscle mass decreases and fat levels increase. Pscyhomotor ability to react to stimuli also decreases with age (Forteza and Prieto, 1994). Forteza and Prieto (1994) also found that visual acuity and adaptability decrease with age. Aging workers will have difficulty focusing on close objects and adjusting to sudden light changes. They also have difficulty locating the source of sound and distinguishing between concurrent sounds.

Warr (1994) classified the relationships between age and the occupation using four different frameworks: 1) age-impaired, 2) age-counteracted, 3) age-neutral, and 4) age-enhanced. This framework was later used by Laflamme and Menckel (1995) in their paper.

Laflamme and Menckel (1995) compiled aging and occupational accidents literature for the last three decades and based on previous research, developed the decremental theory of aging. This theory suggests that as a person advances in age, his or her mental and physical capability to cope with the job demands weaken progressively (Teiger and Villatte, 1987; Teiger, 1989; Sailly and Volkoff, 1990; Davies et al., 1991; Gary, 1991; Laflamme and Menckel, 1995). Despite this, aging workers have the capability to offset the reduction in their mental and physical capabilities by acquiring experiences and by utilizing the resources available in a more efficient way (Salthouse, 1990; Warr, 1993; Warr, 1994; Laflamme and Menckel, 1995). But there are limitations to how far experience can offset these deteriorations. Based on Warr's (1994) framework, Laflamme and Menckel (1995) had characterized various jobs with the age factors. Activities that demand strenuous physical activity, rapid learning and rapid change are considered as age-impaired activities while activities that include skilled-manual and cognitive work are considered as age-counteracted activities. These activities include the task performed by sales staff, mail sorters and psychologist. The third category of activities are those that are not affected by age and are called as age-neutral activities and finally the last category of activities where performance improvement has been determined based on experience or knowledge-based judgments without time pressure are considered as age-enhanced activities.

Johnson (2004) reported that nearly 20 percent of workers between the age of fifty-five and sixty reported that their jobs demand substantial physical effort. Jobs that required physical energy still remain a big issue among aging workers even when Johnson (2004) found that only a small portion of aging workers work in physically demanding jobs and Bolch (2000) found that aging workers received fewer training opportunities than younger workers.

2.2 Factors for Fatalities

Guy Toscano and Janice Windau (1993) found in their study of fatal work injuries from the 1992 national census that workers above the age of 65 years had 13 fatalities per 100,000 workers and workers between the ages of 55 to 64 years had 7 fatalities per 100,000.Workers between the ages of 25-34 years and 35-44 years had 5 fatalities per 100,000 workers respectively. The fatality rate for mining was the highest with 27 fatalities per 100,000 workers followed by agriculture (24) and construction (14). This indicates that mining had the highest fatality rate among all other industries and workers above the age of 55 had higher fatalities rates than any other age group. Guy Toscano and Janice Windau (1996) did the same study using the 1996 national census and found that the number of fatalities in 1996 was the lowest in five years. Mining still had the highest fatalities per 100,000 workers (26.8) followed by agriculture (22.2) and construction (13.9). Using Warr's (1994) framework, mining therefore may be considered to be an age-impaired industry.

Shail Butani (1988) was studying the relative risk of injuries in coal mining using age and experience as the factors. Butani (1988) found that experience exerted a greater influence upon injury rates than age. Butani (1988) concluded that regardless of age, workers with less than 1 year of experience were at higher risk of injury while workers with more than 15 years of experience were at low risk.

Olivia Mitchell (1988) studied the relation of age to workplace injuries. The first problem she encountered in assessing the age-job risk relationship was the difficulty in determining "poor health" among the workers. Data available was based on health problems severe enough to demand medical attention and worker's assessments of their own health conditions were not used in her study. Mitchell (1988) found that workers under the age of 25 were more prone to be involved in temporary injuries while workers over the age of 65 were more prone to be involved in permanent disabilities and fatalities. She also found that occupation rather than industry was more important in explaining the job- risk patterns. Craft workers, transportation operators and laborers appeared to have higher risk for injuries.

J. Paul Leigh et al. (1997) studied the costs of occupational injury and illness across many industries. In order to do this study, they developed their own method – the fatal and non-fatal injuries and illness were collected from the US Bureau of Labor Statistics while the cost data were collected from the workers' compensation records and estimates of lost wages and jury awards. The value expressed in the calculation was based on 1993 US dollars. The greater the number of injuries and the more severe the injuries is, the higher is the total cost. Based on their study, they found that taxicab drivers had the highest average cost per worker at $11,528. This was due to the fact that taxicab drivers were at much higher risk for homicide – in 1996, they recorded 22.7 homicides per 100,000 workers (Toscano and Windau, 1996). After taxicab drivers, bituminous coal and lignite mining workers had an average cost of $8,600 per worker followed by logging workers at $7,009, crushed stone workers at $4,024 and oil and gas field service workers at $3,551. Iron ore mine workers and Copper ore mine workers were ranked 10th and 12th respectively with an average cost of $2,950 and $2,500 per worker, respectively. This indicates that metal and non-metal mines had a lower average cost per worker than coal mines.

Dawn Castillo and Bonita Malit (1997) found in their study of fatal injury deaths of 16 and 17 year olds in the US that the leading causes of death were motor vehicle accidents, homicide and machinery-related accidents. The rates of deaths are comparable or slightly higher than the rates for young and middle aged adult workers. Workers above the age of 55 still have the highest rate of deaths/100,000 FTE (full time equivalent). The rate for workers between the age of 16-17 was 3.51 deaths/100,000 FTE between 1990 and 1992 while the rates for workers between the age of 55-64 is 6.39 and for workers above the age of 65 is 17.48. Though Castillo and Malit (1997) did the comparisons between different age groups, they could not compare the fatality rate among young and older workers in different industries because the data from these industries or occupations of these workers was absent. Therefore, we could not see the fatal injury deaths of 16 and 17 year olds in mines alone. Castillo and Malit (1997) also pointed out that those young workers were more likely to be victims of work related homicides because they worked in retail, grocery stores and restaurants which have greater risks for homicide.

John Ruser (1998) questioned the workplace fatality rates that have been using the number of employees as the denominator. He, on the other hand, suggested hours of work as the denominator which is much closer conceptually in describing workers exposure to hazards. This is because some workers might work part-time while others might work full-time. From this study, Ruser found that fatality rates calculated with hours worked and with employment gave the same relative results when annual hours worked per worker do not vary systematically over the entire worker groups. When hours were used as the denominator, workers above the age of 65 had the fatality rate of 19.2 per 100,000 workers but if the number of employees was used instead, the fatality rate dropped to 14 per 100,000 workers. The fatality rate is a bit smaller if hours were used as the denominator among the 25-34, 35-44 and 45-54 age groups. This means workers in these age groups worked more hours than workers between the age groups of 15-19, 20-24, 55-64 and above 65. Workers under the age of 20 worked only 62% of the hours of the average worker while workers above the age of 65 worked 73% of the hours of the average worker. When hours were used as the denominator in different industries, mining had the fatality rate of 22.6 per 100,000 workers compared to 26.4 per 100,000 workers when the number of employees was used as the denominator. Despite this, mining still had the highest fatality rate among all other industries.

Suzanne Kisner and Stephanie Pratt (1994) did a study on occupational injury fatalities among older workers in the United States between 1980 and 1994. They found that, between 1980 and 1994, workers aged 65 and older had a fatality rate of 13.7 per 100,000 workers compared to a fatality rate of 5.1 per 100,000 workers for workers between the ages of 16 to 64. Older workers above the age of 65 were 2.5 times more likely to be involved in fatal accidents. Mining had the highest fatality rate among all other industries for these older workers (64.4 per 100,000 workers), followed by agriculture/forestry/fishery (49.9). This rate would be higher if exposure hours were used as the denominator.

Chi a-Fen Chi and Meng-Lin Wu (1997) studied the relationship between fatality rate and age in Taiwan. They found that the interaction effect between the type of industry and the age of the workers for fatality rates was significant. They also found that the fatality rate among older workers experienced a significant rising trend for falls, collapse and being struck by falling objects while the fatality rate of electric shock declined significantly with age. Workers with 15 years or more experience had lower-than-average risk.

Barbara Fotta and George Bockash (2000) found that the annual percentage of injured workers in metal and non-metal mines among aging workers (above the age of 45 years) has risen from 27% in 1988 for metal mines to 38% in 1998 while for non-metal mines, the proportion has risen from 23% to 34%. They found that iron ore operations and alumina mills have the largest proportion of injured/ill older workers at 46.3% and 44.9% respectively, while dimension stone mines had the lowest proportion at 17.8%. In the bituminous coal operation, they found that based on the distribution of workers, workers aged 45 and above are more likely to be injured in surface coal mines than underground and among the surface workers, proportionally more injured/ill older workers are in preparation plants than at surface production operations. As the employment size of coal mine increases, so does the proportion of older injured/ill workers. For an example, 61.1% of injured/ill workers in mine with 250 workers and more in surface coal mines are above the age of 45 while only 44% were above the age of 45 for surface coal mines with fewer than 20 employees.

Glenn McEvoy and Wayne Cascio (1989) used meta-analysis to conclude that age and performance are generally unrelated – all mean correlations for overall samples were relatively small. They came to this conclusion by collecting data from 96 independent studies that reported age-performance correlation. The sample size of these 96 independent studies was 38,983 workers. These workers represented a broad cross-section of jobs and age groups. McEvoy and Cascio (1989) found that the correlations between age and performance ranged from -0.44 to +0.66 with 56 studies reporting positive correlation while 38 studies showed negative correlation and two showed a correlation of 0.00.

Based on these studies, they concluded that the relation between age and performance was only slightly positive.

Vladislav Kecojevic and Zainalabidin Md-Noor (2009) in their study of hazard identification for equipment related fatal accidents in underground coal mining found that the major hazard for mining equipment-related fatal incidents is “Failure of victim to respect equipment working area”. They suggested that new workers should be trained to be familiar with equipment that they will be working with. Inexperienced workers should be trained by computer-based simulation training and mentored and supervised by experienced workers.

Vladislav Kecojevic et al. (2007) performed an analysis of equipment-related accidents in mining operation from 1995-2005 and found that haul trucks represented the greatest proportion of the total fatalities (22.3%), followed by belt conveyors (9.3%) and front-end loaders (8.5%). They also found that workers with less than five years of experience represented 44% of all fatalities in the period of 1995-2005.

W.A. Groves et al. (2007) did an analysis of fatalities and injuries involving mining equipment. They used data from both the Mine Safety and Health Administration (MSHA) and the Current Population Survey (CPS). Off-road ore haulage was found to be the most common source of fatalities while non-powered hand tools was the most common source of non-fatal injuries. They found that workers above the age of 55 had an elevated risk for fatality while younger workers had an elevated risk for injury. The majority of the incidents involved workers with less than 5 years of experience.

3. Method

Data of fatal accidents in metal and non-metal mines from 2002 to 2006 were collected from the Mining Safety and Health Administration (MSHA) website. Metal and non-metal mines include gold ore, iron ore, copper ore, limestone, cement, sand and gravel, potash, phosphate rock, stone, granite, alumina, Trona, clay and other type of metals and non-metals. Based on the literature review, the hypotheses- older workers with the least experience and workers in small mines would represent the highest fatality in metal and non-metal mines from 2002 to 2006 are tested.

In order to test the hypotheses, the fatal accidents were categorized into three categories: (1) the **Size** of the mine using the number of employees; (2) the **Age** of the workers; and (3) years of job **Experience** the workers had. The factors are shown in Table 1.

Table 1. Description of the factors (*Source:* Qiu, 2008).

	Factor	Description
1	Size	The size of the mine where an accident occurs is based on the number of employees working in metal and non-metal mines
2	Age	The age of the workers killed in accidents
3	Experience	The number of years the worker had worked in the job. It is imperative to differentiate between the job experience and the mining experience as indicated in the literature review. In this thesis, only job experience will be used.

These three factors are further divided into three categories based on results obtained from previous research. For example, Butani (1988) found significant differences in risk of injuries between workers with less than 1 year, between 1 and 15 years and more than 15 years of experience. This result is used to categorize **Experience** into five different groups – these groups are defined in Table 2 and Table 3. A minimum of five categories was also needed to test relation between Age and fatality rate (Warr, 1994). **Age** is also categorized into five different **Age** groups as shown in Table 2 and Table 3. **Size** is divided into three categories and not into five categories in order to reduce the number of combinations for the factors.

Table 2. Categorical Factors and Their Descriptions (*Source:* Qiu, 2008).

Factors	Type	Range	Notes
Mine Size	categorical	1,2,3	1 has the fewest workers in the same mine, 3 has the most workers in the same mine
Age	categorical	1,2,3,4,5	1 is the youngest, 5 is the oldest
Experience	categorical	1,2,3,4,5	1 has the least experience, 5 has the most experience

The detailed descriptions of the factors are shown in Table 3.

Table 3. Detailed Description of the Factors (*Source*: Qiu, 2008).

Factor	Group	Notes
Size	1	The number of employees between 1 to 50
	2	The number of employees between 51 to 100
	3	The number of employees more than 101
Age	1	17- 24 years old
	2	25-34 years old
	3	35-44 years old
	4	45-54 years old
	5	More than 55 years old
Job Experience	1	Less than 1 year
	2	Between 1 and 5 years
	3	Between 5 and 10 years
	4	Between 10 and 15 years
	5	More than 15 years

Histogram was first created to see the pattern of fatalities based on Age, Experience, and Size (Qiu, 2008). These allowed us to see which Age group, Experience group and Size group have the highest number of fatalities. Figure 1 shows the histograms.

Figure 1. Histograms of Size, Age, Experience and Year and the Frequency of Fatalities

After we recognized the pattern of fatalities, the independence of the various variables to each other was tested. This was done because ANOVA (analysis of variance) can only be used to test the interactions of independent variables (Qiu, 2008). Apart from being independent to each other, the responses in ANOVA must also be normally distributed (Qiu, 2008). One way to check this normality is to check the residual plots. Figure 2 shows that Age and Experience has a P-Value of 0.000, indicating that they are both highly correlated. This means Age and Experience are not independent to each other and therefore must not be included in the ANOVA model (Qiu, 2008).

Tabulated statistics: Age, Experience

Using frequencies in Total

Rows: Age   Columns: Experience

	1	2	3	4	5	All
1	10	7	1	0	0	18
2	7	13	1	2	0	23
3	11	13	5	3	6	38
4	11	10	7	3	12	43
5	5	4	4	2	19	34
All	44	47	18	10	37	156

Cell Contents: Count

Pearson Chi-Square = 47.493, DF = 16, P-Value = 0.000

Likelihood Ratio Chi-Square = 54.163, DF = 16, P-Value = 0.000

* NOTE * 11 cells with expected counts less than 5

Figure 2. Tabulated Statistics for Age, Experience

Next, the correlation between Size and Experience were tested. The P-value of the Chi-Square test for Size and Experience is 0.264. This indicates that Size and Age are independent to each other.

3.1 Recommendations

Since Age and Experience are highly correlated, both of them would not be included in the model. Instead, one possible way is to leave one of them out of the model. The other way is to define a new variable based on Age and Experience (Qiu, 2008). This variable can be defined as AgeSubtractExperience (Qiu, 2008). This variable is created to study the interactions of the two highly correlated variables- Age and Experience. By creating this new variable, the interaction of these two variables and the Size can be studied. The definition of this new variable is shown as below:

If (Age – Experience = 0) AgeSubtractExperience=0;

If (Age – Experience = -1) AgeSubtractExperience=-1

If (Age – Experience < -1) AgeSubtractExperience=-2

If (Age – Experience = 1) AgeSubtractExperience=1

If (Age – Experience >1) AgeSubtractExperience=2

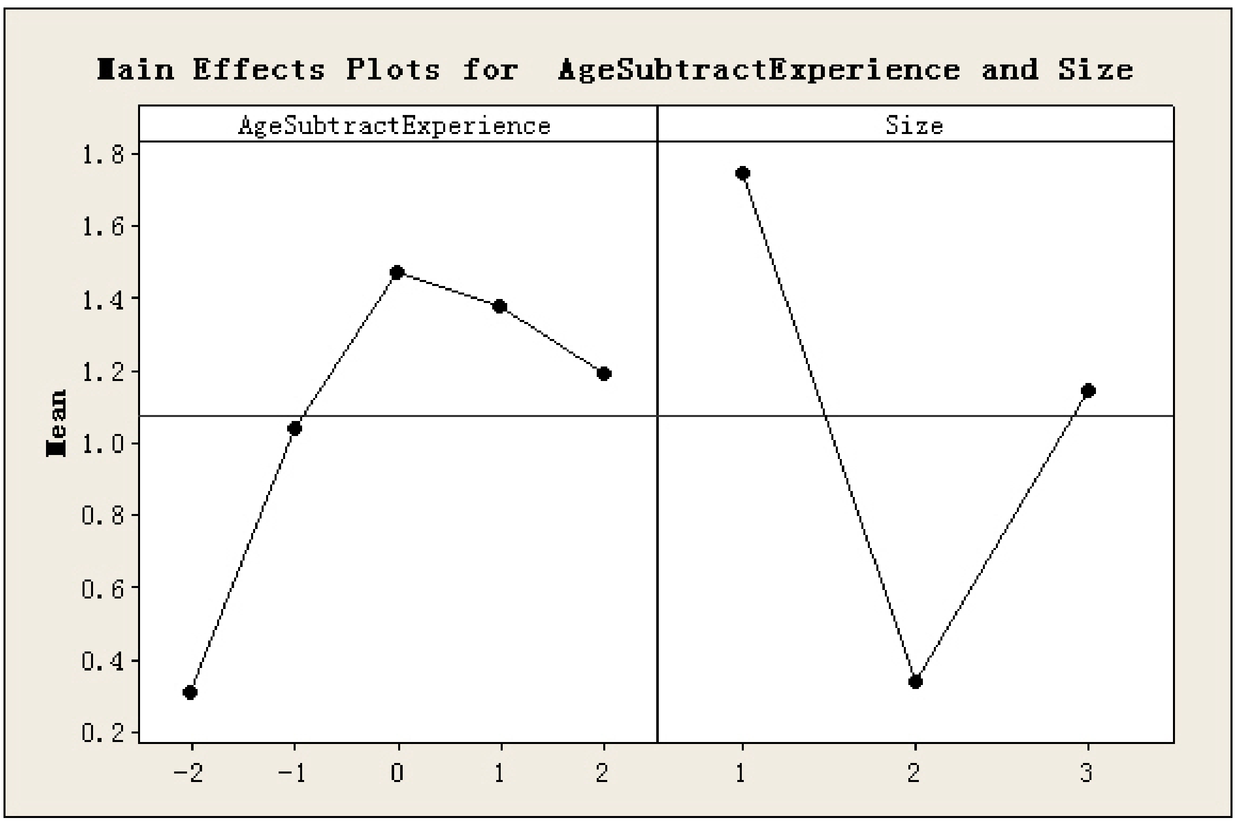

Figure 3. Main Effects Plots

In Figure 3, for the main effect of Size, medium size mine has the lowest mean. And for the main effect of AgeSubtractExperience, workers with Age>Experience (AgeSubtractExperience>0) have higher mean than those workers with Age<Experience (AgeSubtractExperience<0), and workers with Age=Experience (AgeSubtractExperience=0) have the highest mean.

3.2 Confounding Factors

Workers in **Age** group 1 (17-24 years) cannot have more than 10 years of experience. To solve this problem, only workers in Age groups 3, 4 and 5 were included and **AgeSubstractExperience** was defined as follow, result shown in Figure 3 was obtained:

If (Age – Experience = 0) AgeSubtractExperience=0;

If (Age – Experience = -1) AgeSubtractExperience=-1

If (Age – Experience < -1) AgeSubtractExperience=-2

If (Age – Experience = 1) AgeSubtractExperience=1

If (Age – Experience >1) AgeSubtractExperience=2

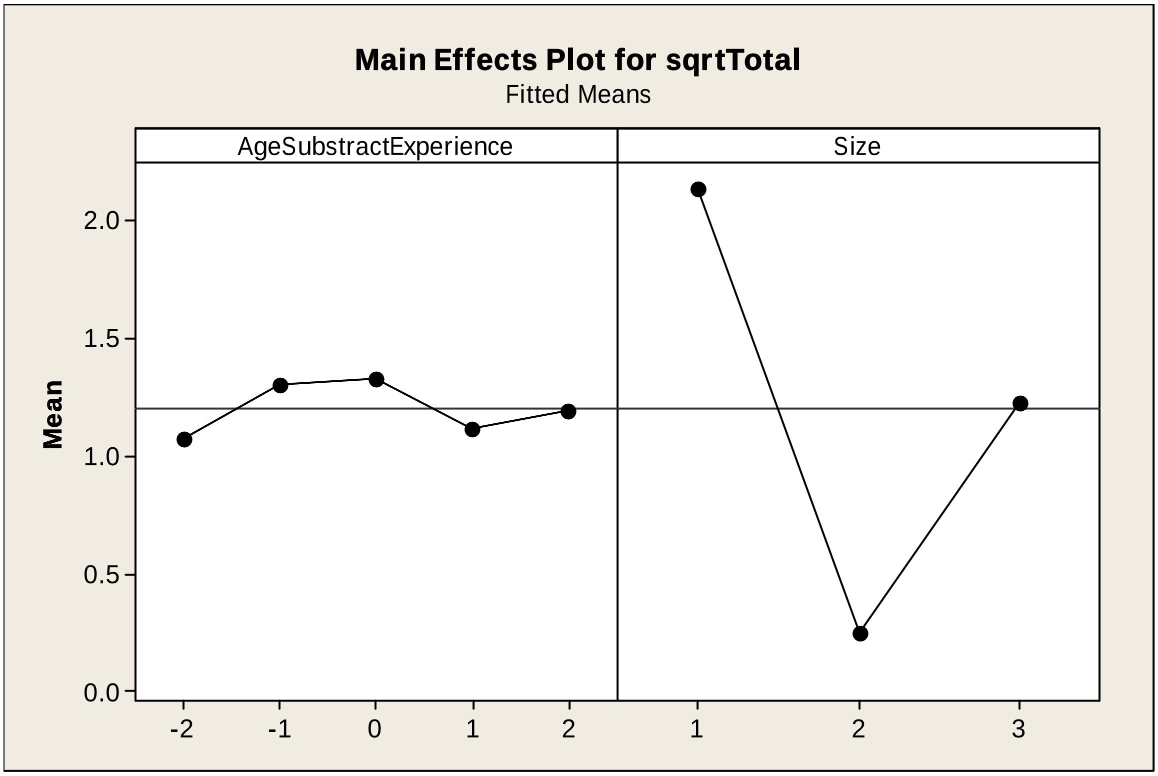

Figure 4. Main Effect Plots when Age groups 1 and 2 are removed

3.3 Fatality Rate Per 100,000 Workers

To test which **Age** group has the highest fatality rate per 100,000 workers, Equation 1 is used:

Fatalities per 100,000 workers = (Number of fatalities/Total number of workers) × 100,000 (Equation 1)

The demographics data of the metal and non-metal mines are found in population survey collected by the Bureau of Labor Statistic (BLS). This population survey lacked detailed demographics data of the workers - only the Age group demographic was available. The National Institute of

Occupational Safety and Health (NIOSH) is currently working on collecting detailed demographics breakdown of the mine workers.

3.4 Risk Index

To find which Age group has the highest risk index, Equation 2 is used. Risk index measures the relativity of fatalities using the percentage of fatalities and workers on each Age group

Risk index = Percentage of fatalities attributed to a given age group/ Percentage of total workers attributed to a given age group (Equation 2)

3.5 Class of Accidents

Based on the fatalgram, a publication available on the MSHA website, the class of accidents for the fatalities in metal and non-metal mines from 2002-2006 can be identified and categorized .These class accidents include powered haulage, machinery, fall of material, fall of person, electrical, explosion, hoisting and others (MSHA, 2007).The definition of these class accidents is given below:

1) Powered haulage – Accidents involving the motion of powered haulage equipment from conveyor to pickups and automobiles.
2) Machinery – Accidents related to the motion of machinery from drills to compressors
3) Fall of material – Accidents caused directly by falling material other than material from the roof or face.
4) Fall of person – Accidents include slips or falls while getting on or off machinery and haulage equipment which is not moving.
5) Electrical – Accidents in which the electrical current is most directly responsible for the resulting accident.\

4. Results

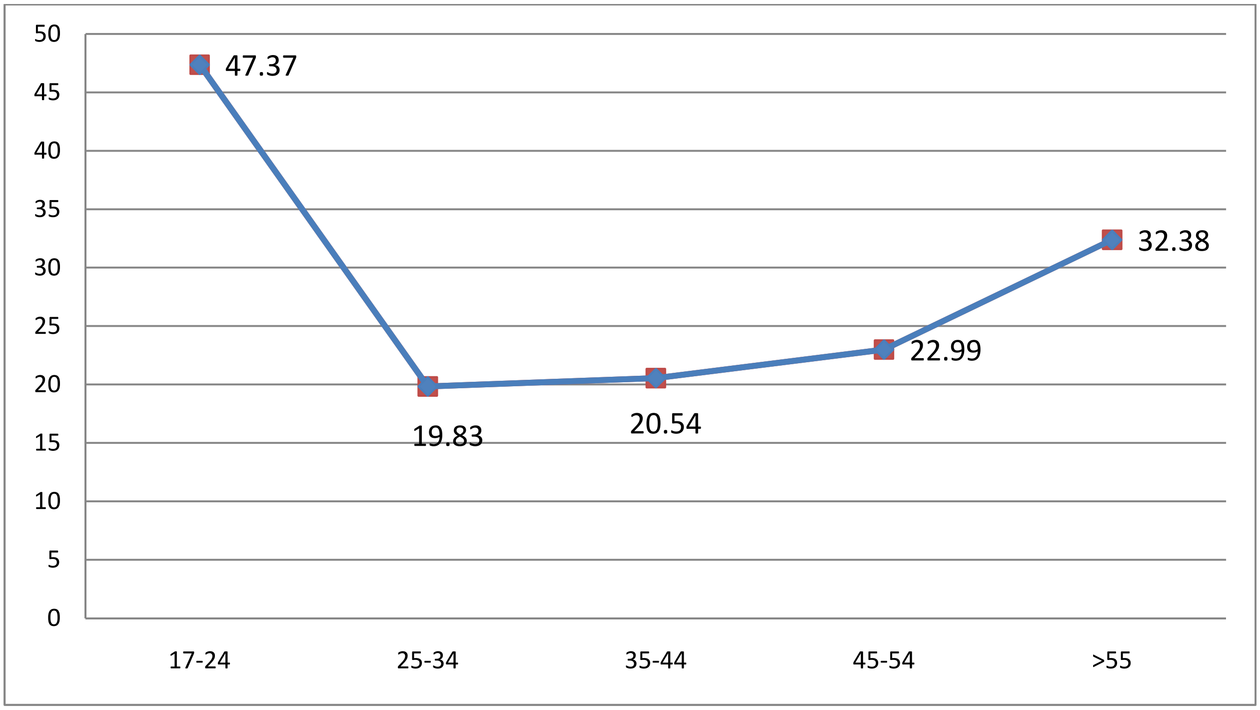

Figure 5. Fatalities per 100,000 workers based on age group in metal and non-metal mines from 2002 to 2006.

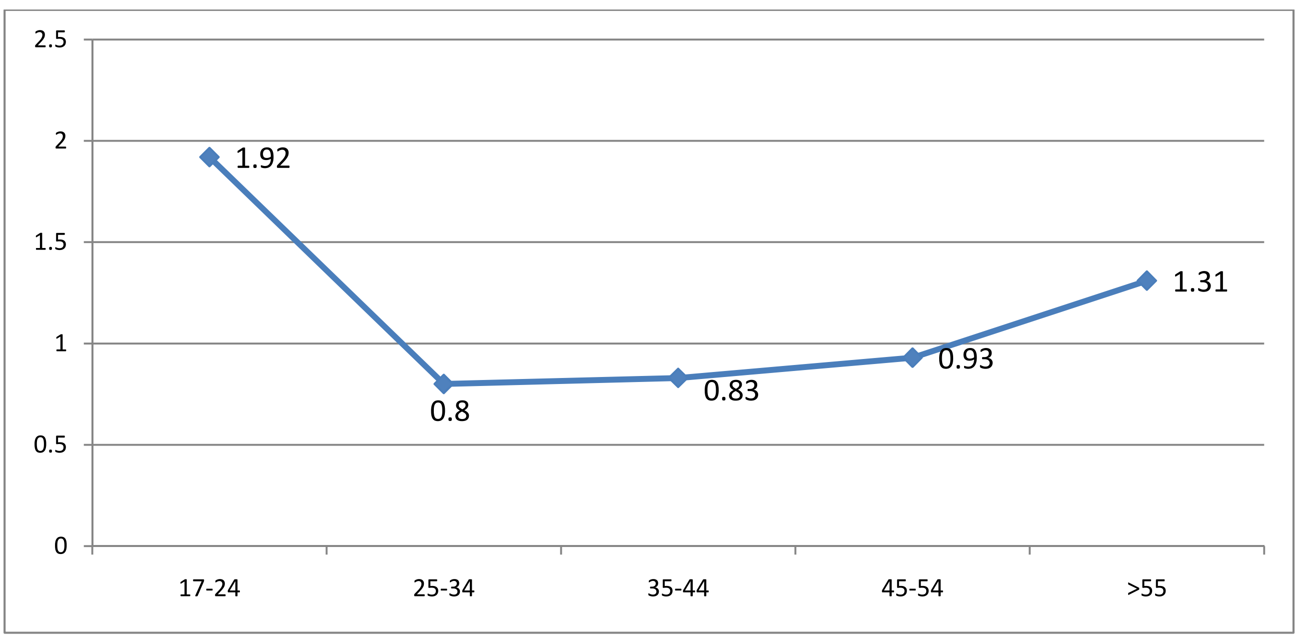

Figure 6. The risk index based on age groups in metal and non-metal mines from 2002 to 2006

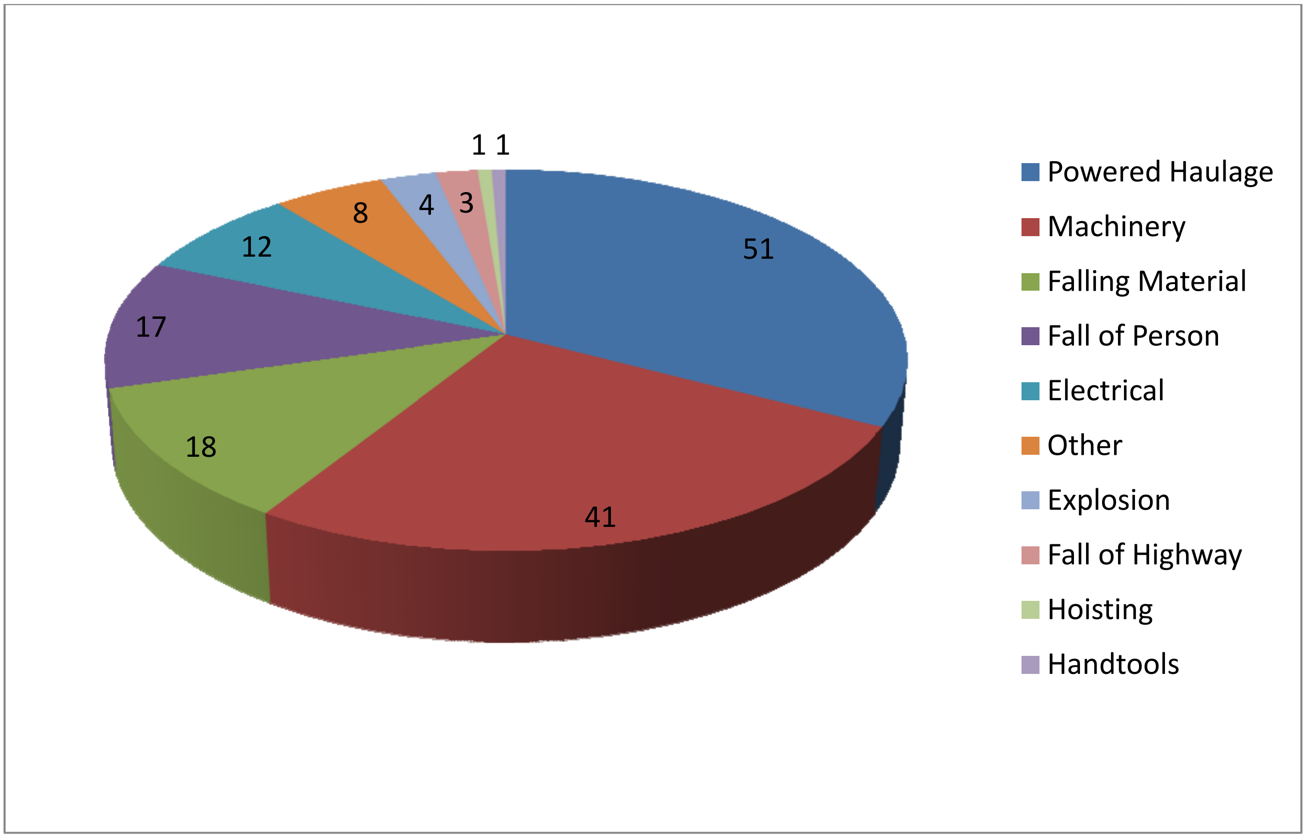

Figure 7. Numbers of death based on class of accident in metal and non-metal mines from 2002-2006.

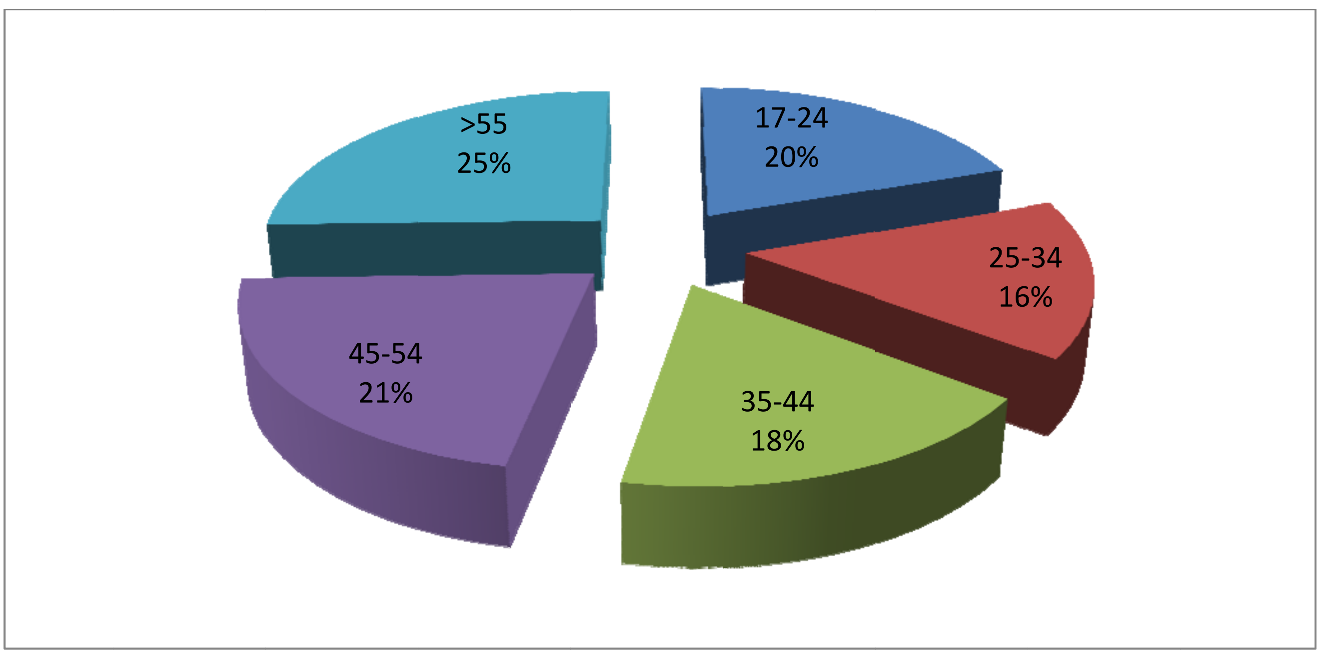

Figure 8. Percentage of workers based on age group involved in power haulage fatalities.

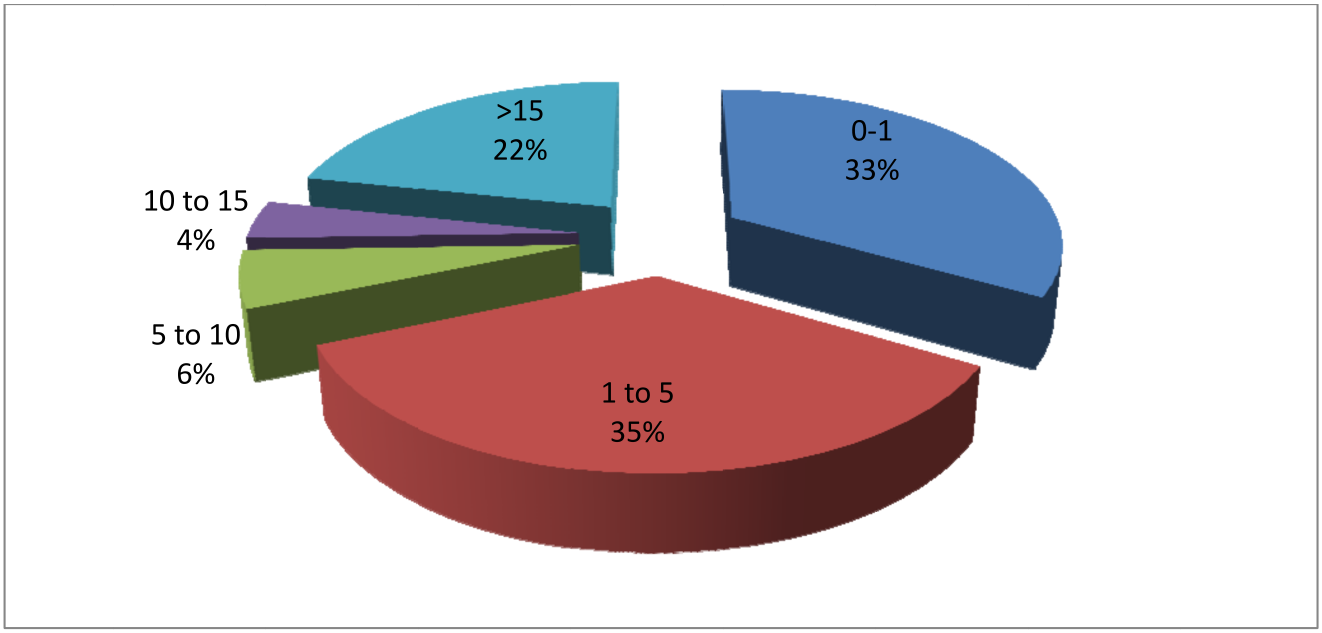

Figure 9. Percentage of workers based on years of job experience involved in power haulage fatalities.

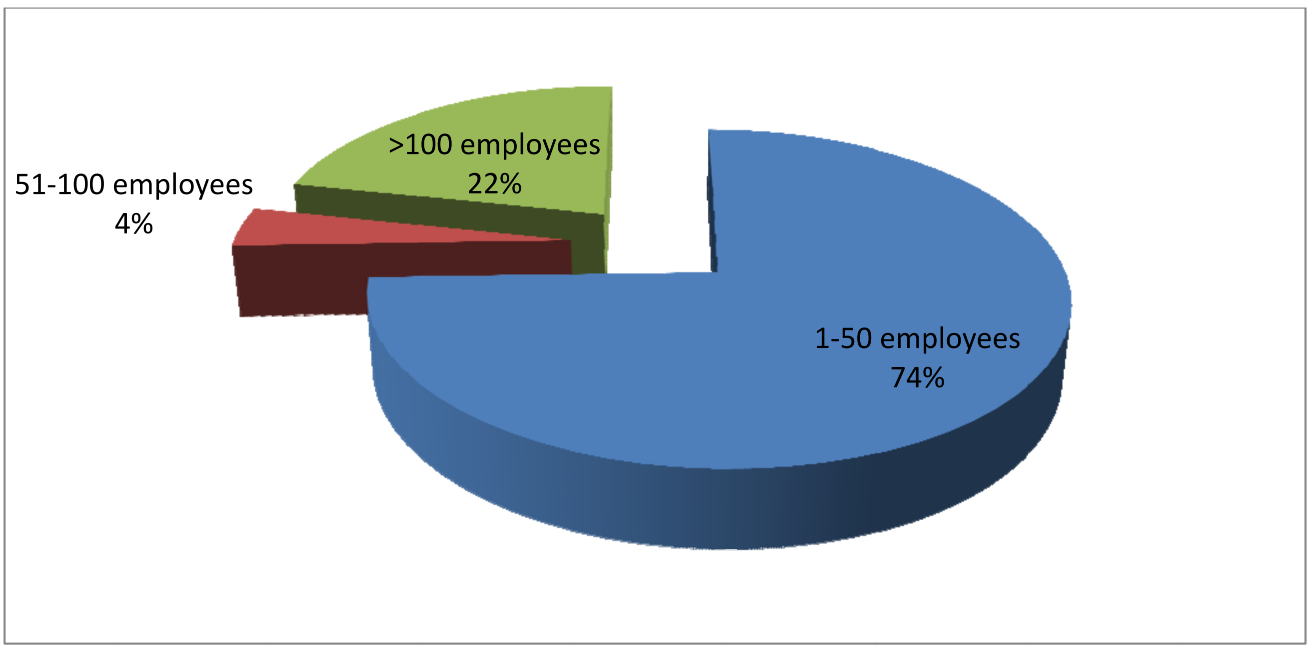

Figure 10: Percentage of workers based on the size of the mine involved in power haulage fatalities

5. Discussion

The fatalities in metal and non-metal mines between 2002 and 2006 were more likely to involve workers belonging to the same Age group and Experience group – for example, younger workers with the least experience and older workers with the most experience. Workers who belong to one larger Experience group than Age group - for example, Age group 4 and Experience group 5, have the second highest probability to be involved in fatalities between these five years. When the confounding factors (Age groups 1, 2 and 3 are removed and the definition of older workers is brought down to 45 year old), older workers (over 45 years old) with experience more than 10 years have the highest rate for fatalities. This contradicts the conclusion made by Chia-Fen Chi and Meng-Lin Wu (1997) and Butani (1988) in their studies when they found workers with 15 years or more experience had lower-than-average risk. Chia Fen Chi and Meng-Lin Wu (1997) did not do any statistical test to arrive to that conclusion.

Older workers are more likely to be involved in fatalities in the two highest classes of accidents – powered haulage and machinery than younger workers. These older workers also tend to have at least 5 years of experience and some as high as 31 years. These explain why older workers with the most experience have higher probability to be involved in fatalities – they are more likely to be involved in powered haulage and machinery fatalities. When an older worker with 31 years of experience can be involved in fatalities, age might play a bigger role here. Perhaps suggestion made by Nygard (1999) that the physical load for older workers should be reduced by 25% should be applied in metal and non-metal mines. The reduction of physical strength with age can also be a factor why older workers are more likely to die in accidents (Warr, 1994; A.A. Sterns, Sterns and Hollis, 1996).

While the results show that older workers with the most experience have higher rate of fatalities, a strong conclusion cannot be made without first knowing the proportion of older workers in each Experience group. Older workers are probably going to have job experience more than 10 years since they have been working many years but this does not mean older workers with very few years of experience did not exist. In 2005, for example, two older workers (56 and 64 years old) died in truck accidents and both of them had 0.1 year and 1.3 year of experience. There were also workers who died at the age of 66 with 0.2 year of experience and at 55 with 1.7 year of experience in other class of accidents. These showed that older workers who died in metal and non-metal mines between 2002 and 5005 did belong to Experience group 1 and 2.

Based on the risk index (RI), it is best to conclude that younger workers have higher risk for fatalities in metal and non-metal mines between 2002 and 2006 than older workers (without including years of experience). The RI of each Age group – 1.92 for Age group 1 (17-24 years) and 1.31 for Age group 5(above 55 years) show an elevated risk for fatality with younger workers having almost 45% higher risk index than the older workers. While this agrees partly with the conclusion made by W.A. Groves et al. (2007) that workers over the age of 55 years had an elevated risk for fatality; it does not agree with previous studies done by Castillo and Malit (1997), Kisner and Pratt (1994) and Fotta and Bockash (2000) that showed older workers suffered fatalities at higher rate than younger workers. The axiomatic that mining might be an age-impaired job using Warr's (1994) framework might not be true in all cases as the risk index indicates.

It is also important to note that younger workers and older workers have different rate of fatalities in different class of accidents as suggested by Chian-Fen Chi and Meng-Lin Wu (1997). Younger workers represent only 13% of total fatalities involving powered haulage while workers above the age of 35 represented most of the fatalities involving powered haulage. Young workers were also involved in a smaller fraction of the total fatalities involving machinery. It was only for the case of falling material, that almost similar numbers of older and younger worker were involved in the fatalities. Older workers and younger workers might be working in different proportions in various jobs. Perhaps, older workers with many years of experienced work with powered haulage or machinery while younger workers work as electricians. This job assignment might also explain why older and younger workers have different profiles for fatalities.

Another important point to note is – when experience are taken away from the analysis, younger workers have higher risk for fatalities than older workers but when age and experience are both included in the analysis, older workers with more experience and younger workers with the least experience have higher probability for fatalities. So the factor and the combination of factors used to do the analysis are important.

Most of the fatalities also came from mines with less than 50 employees. If the class of accident was taken into consideration, large mines have lower rate of fatality in most classes of accident except in the falling person accident. The lack of safety culture is considered as a factor for higher percentage of fatalities from small mines (Grayson, Winn, Elliot, 1995). They believed that "cultural approaches of training and indoctrination" to address fatalities in metal and non-metal mines may or may not be successful in small mines and among miners. Often, workers in small mines have to be involved in various tasks in the mines compare to workers in large mine. Safety professionals also tend to wear many hats in small mines compare to large mines. All of these play a role in why small mines have higher number of fatalities.

5.1 Limitations

The absence of detailed demographics data has been a huge obstacle in coming out with strong conclusions - there are no breakdown of demographics based on years of experience and the size of the mine. This prevents the calculation of risk index and fatality rate per 100,000 workers for years of experience and the size of mine. NIOSH Pittsburgh is currently working on collecting these demographics data. Furthermore, there are many other factors that might lead to fatalities in metal and non-metal mines. As pointed out by Ringenbach and Jacobs (1995), there are varieties of reasons that caused injuries in the workplace. These reasons might include organizational factors and individual characteristic. While the age and experience of the workers might be considered as individual characteristic, the number of employees in the mine and the safety culture of the mine are considered to be the organizational factors. All these factors play a role in causing injuries and fatality in the metal and non-metal mines between 2002 and 2006. This study on the other hand was only done using three factors – size of the mine, years of experience and age of the workers while ignoring other factors.

5.2 Future Research

The relationships between years of experience and fatalities should be determined with the demographics study. Warr's (1994) framework should be applied to other workers such as experienced and autistic workers because not all type of tasks in the workplace can be considered as experienced-enhanced or autism-impaired tasks. Interventions should also be developed to reduce the incident rates based on the profiles of fatalities and injuries.

6. Conclusion

Job experience would not reduce the risk for fatalities. While younger workers had the highest risk for fatalities in metal and non-metal mines, older workers had the second highest risk for fatalities. Companies should recognize this fact and consider introducing safety training and cultures to workers who have many years of job experience.

Companies should also recognize that older workers and younger workers have different profiles of fatalities. It is important for safety professionals to study the pattern of injuries and fatalities based on age and years of experience in order to create effective interventions in the workplace. By studying the profiles of fatalities and injuries, companies can determine the age-based fatalities accordingly.

The prejudice that somehow older workers are incapable of working in metal and non-metal mines and should be substituted with much stronger young workers should be examined. Older workers and younger workers have strengths and weaknesses that they bring to the companies and it is for the companies to decide on how to use these strengths and weaknesses wisely.

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