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AN ANALYSIS OF FATAL INCIDENTS IN METAL AND NON-METAL MINES FROM 2002- 2006

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Abstract

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, are 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.

By using the population survey provided by the Bureau of Labor and Statistics (BLS), the fatalities per 100,000 workers were also calculated. Workers between the ages of 17 and 24 had the highest rate of fatalities per 100,000 workers (47.37), followed by workers over the age of 55 (32.38). For the risk index (RI), workers between the ages of 17 and 24 had a RI of 1.92. This RI indicates that workers in this age group had higher risk to be 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 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. Workers working in small mines (1-50 employees) have a higher risk for death than workers in medium-size mines (51-100 employees) and large mines (more than 100 employees) except for “ falling person” in which most of the deaths came from the large mines (59% of the total deaths).

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To my beloved nephew, Imran Haazim – who was born a week after I arrived at Penn State to pursue my Master’s and who passed away suddenly 6 months later.

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Chapter 1

Introduction

In the Greek epic of Oedipus, Oedipus became the king after solving the famous riddle of the Sphinx: "What creatures walked on four legs in the morning, two in the noon and three in the afternoon?" The answer was the three stages of human life - from crawling baby to adulthood to old age (Moody, 2002). From the dawn of civilization, humans have been perplexed by the process of aging, and various stages of life have been defined differently by these ancient civilizations (Moody, 2002). Homer's Iliad worshipped the youth of Achilles and revered the aged Nestor for his wisdom; Aristotle viewed the middle-age as the pinnacle of life while Plato revered the later life (Moody, 2002). Reformation and Renaissance gave new explanations to the concept of aging and the various stages of life (Moody, 2002). Shakespeare believed in the "seven ages of men" when he penned the following scene:

All the world's a stage
And all the men and women merely players,
They have their exits and entrance;
And one man in his time plays many parts,
His acts being seven ages

(As You Like It, Act 2, scene 7)

For Shakespeare, we are all actors that are playing our "roles" and our roles change with the process of aging (Moody, 2002). It was later in 16^{th} and 17^{th} century Europe as life expectancy increased, childhood is separated from adulthood and old age (Aries, 1962). Table 1 shows that the life expectancy of humans has increased drastically while the maximum approximate life span has been lingering around the 100 years mark. The chimpanzee, which shares 99% identical DNA with humans, only has a maximum life span of 50 years. This difference might suggest a limited relationship between genetic mechanism and the rate of aging (Moody, 2002). If genetic mechanism plays a very small role in aging, we can therefore try to intervene in order to delay the process of aging (Finch, 1990).

Table 1: Average Mortality Rate of Homo Sapiens (Cutler, 1976).

Time Period	Life expectancy (year)	Approximate maximum life span(year)
70,000 – 30,000 B.C.	29.4	70
30,000 – 12,000 B.C.	32.4	100
12,000 – 10,000 B.C.	31.5	100
10,000 – 8,000 B.C.	38.2	100
Greece (1100 B.C. – A.D. 1)	35	100
Rome (753 B.C. – A.D. 476)	32	100
England (1276)	48	100
England (1376 – 1400)	38	100
United States (1900 -1902)	61.5	100
United States (1950)	70	100
United States (1970)	72	100
United States (1980)	73	100

The increase in life expectancy had led to the creation of a new "*social clock"*. The idea of the "s*ocial clock"* was invented in civilizations to define the appropriate age for life events (Decker, 1980). For example, in the modern western civilization, older workers who have reached the age of 65 are expected to retire; however, in modern eastern civilizations such as India, the age of retirement is 58 and in China, it is 60 for males, and 55 for females. The "s*ocial clock"* therefore changes from one culture to another and from one period of time to another.

The overall demographic transition of population aging, due to a low fertility rate coupled with a low mortality rate, has increased the number of persons aged 60 years from 204 million in 1950 to 1.9 billion in 2050; consequently, the way of we look at aging workers and our "*social clock"* may change (UN, 1998). Between 1946 and 1964, 78 million babies were born in America (Silverstein, 2008). This generation is collectively known as the 'baby boomers'. Currently in the year 2009, these 'baby boomers' ranged from 45 to 63 years of age and will increase the number of workers 55 and older by 49% between 2004 and 2014 (Toossi, 2005). The Social Security program's retirement age is predicted to rise to 70 in the future from 62 in 1985 (Quinn, 2002; Cahill et al., 2005; Coy and Brady, 2005). Given how the incentives to retire early have been softening, the labor force participation rate among 55-64 year olds increased from 54% in 1985 to 62% in 2004; the labor force participation rate for those between 25-54 years old remained stable – fluctuating between 82% and 84% (Toossi, 2005).

1.1 What's in a name?

How should we define "aging workers"? Do "aging workers" have any objection to be referred as such? When the National Council on the Aging conducted a national sample survey in 1975, it found that 50 percent of Americans liked the phrases, '"a mature American," "a retired American," and "a senior citizen," while 15 percent of Americans disliked all these phrases (Decker, 1980). Additionally, 50 percent of those surveyed did not like phrases such as, "an aged person" and "an old man/woman." Decker (1980) believed that people over the age of 65 disliked the phrases "an aged person" and "an old man/woman" because these phrases seem so absolute. "An aged person" suggests that the aging process has been completed and "the total agedness has been reached." Decker (1980) therefore suggested using descriptive terms such as "younger", "middle-aged", and "older" to compare the various age groups.

Gerontologists use the term *normal aging* to describe the irreversible process that is an intrinsic part of every species (Moody, 2002). Arking (1998, p. 11) described aging as a "time-dependent series of cumulative, progressive, intrinsic, and harmful changes that begin to manifest themselves at reproductive maturity and eventually end in death." Social gerontologists typically have a positive view of the aging process although these views are not shared universally. One sociological standpoint argues that aging can be best described as a period without any role (Burgess, 1960; Blau, 1981). Rosenmayr (1984) on the other hand believed that aging can bring an unexpected form of "late freedom." Strehler (1982) suggested that fundamental age-related changes must be defined by these four conditions: 1) must be deleterious, that is, they must reduce function, 2) progressive and gradual, 3) intrinsic and not affected by a modifiable environmental agent, and 4) universal (Arking, 1998). The fourth condition that aging must be universal is not fully accepted by gerontologists (Arking, 1998; Moody, 2002). Finch and Kirkwood (2000) found that it is not possible to assume all members of a species age in an identical manner. Therefore only three of Strehler's conditions, deleterious, progressive, and intrinsic, can be used to describe the aging process (Arking, 1998). If that is the case, then how could we define "aging workers" as a set of people with almost identical physical and intellectual abilities? Can we lump a diverse set of people bound only by their chronological age into one big category?

1.2 Why do we age?

There are two hypotheses from the modern evolutionary theory that attempt to explain the reasons why we age. The *mutation accumulation hypothesis* proposed that new mutations are always being generated at a low rate in the population (Medawar 1946, 1952; Williams 1957; Arking, 1998). These early mutations are harmful and would be selected against. Mutations in later life would not be selected against because most of the organisms that carried these mutations have died at an earlier age. The failure of natural selection to stop these mutations leads to their accumulation and older organisms would exhibit these "late-acting deleterious mutations" (Arking, 1998).

Williams (1957) meanwhile proposed the *antagonistic pleiotropy theory* (Arking, 1998). Pleiotropic genes are genes that have beneficial effects in early age and deleterious effects on later life. These pleiotropic genes also accumulate due to the failure of natural selection to cease accumulation (Arking, 1998). This is due to the premature death of the carriers of these genes. This can be seen in the effects of proinflammatory response in the young and in the elderly (Arking, 1998; Van Den Biggelaar et al., 2004). The proinflammatory response increases the survival of the young by resisting infections. However, this response increases cardiac mortality in the elderly.

If evolution is viewed as a mechanism for passing genes to the next generation instead, then fecundity can reduce the life span of an organism (MacArthur and Wilson, 1967; Arking, 1998). Organisms with high birth rates have high mortality rates, while organisms with low birth rates have much lower mortality rates (MacArthur and Wilson, 1967; Arking, 1998). Humans belong to the category of organisms with low birth rates and therefore have low mortality rates, as well as slow maturation, and the ability to reproduce many times.

1.3 Graying of the workforce

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 U.S. Bureau of the Census, in 1996, the participation rate for men age 55-64 years in the workforce was 66% and for women age 55-64 years, the participation rate in the workforce was 49%. The participation rate for women has increased 8% since 1980, while for men it has decreased by 6% (Hansson et al., 1997). Besl and Kale (1996) found that high divorce rates prevent older women from accessing pensions and therefore increase their participation in the workforce. In 2003 alone, workers above the age of 45 represented almost 45% of the mining workforce (Kowalski et al., 2005). That does not mean that the older the workers are, the more likely they to be involved in work-related problems; 43% of workers age 45-54 years reported work-related problems compared to only 24% among workers age 55-64 years (Aldwin et al., 1996).

Those considered as “aging workers” are also getting younger. The U.S. Department of Labor considers workers “old” when they reached the age of 45 while the American Association of Retired Persons (AARP) on their national survey included workers aged 45. Some managers in the United Kingdom consider 45-year-old workers as "old" (Metcalf and Thomspon, 1990; Arrowsmith and McGoldrick, 1996). However, aging workers are also getting older. In Japan, for example, the number of Japanese workers who are in their nineties has increased recently (Watanabe, 2005).

Silverstein (2008) believed that "older workers are in some ways more productive and most skilled but in others are the most vulnerable." 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). Agriculture/forestry/fishing represented 35% of the fatalities among workers over the age of 65, followed by services (11%), construction (11%), manufacturing (11%) and retail trade (10%) (Kisner and Pratt, 1997). 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.

1.4 How aging workers are perceived?

Kogan and Shelton (1932) found that children had negative attitudes toward aging people while Thomas and Yamamato (1975) found that grade-school and high-school students had favorable views about aging people. This might be explained by the variation in the level of education and generational differences between these two sets of subjects. Auerbach and

Levenson (1977) in their study of college students found that college students had positive attitudes toward older people, but these favorable attitudes decreased drastically when they had to take classes with older people. These college students felt that older people in the class tend to identify themselves with the instructor, and share stories of their personal lives and past experiences, therefore causing irrelevant digression in the class. The study suggested that attitudes toward older people can be changed and that interactions with older people are important to shape attitudes toward them. Because there was a drastic decline in positive attitudes towards older people in a classroom setting does not mean that the same result will be obtained in other settings. Aging workers could be viewed positively for sharing their work experiences with younger workers.

Cockerham (1977) introduced ***modernization theory,*** which suggests the status of older people in modern culture will decline over time in the future (Decker, 1980). This is contradictory with the status of older people in farming and land-owning societies where older people are highly respected and tend to own the land and the properties. This ***modernization theory*** of aging is supported by other research that showed the loss of status among older people when urbanization and social mobility took place (Cowgill and Holmes, 1972; Decker, 1980). So much so, Palmore and Manton (1974) believed the key element of modernization is the loss of status of older people.

Rowe and Minaker (1985) found that there are barriers when communicating with aging people. Aging people have a high prevalence of hearing disorders (22 percent), visual deficits (15 percent), and communication difficulties linked to mental and nervous disorders (10 percent). Additionally, Blazer and Williams (1980) found that the incidence of depression is high (15 to 30 percent) in the elderly.

The nature of the job affects how older applicants are rated by others (Perry, Kulik and Bourhis, 1996). Age discrimination among applicants increased when video interviews and video resumes were used. The International Foundation for Employee Benefit Plans found that although 86% of Fortune 2000 companies say they value older workers, only 23% have a policy that encourages the hiring of older workers (Capowski, 1994). Workers between the ages of 55 and 64 years also complained that they received less training opportunities than workers between the ages of 35 and 44 years (Simon, 1996).

The concept of successful aging has entered the vocabulary of ordinary Americans. The sentiment that aging is not about decaying into frailty and senility has started to take root in American culture (Rowe and Kahn, 1997). "Life-long learning" and "You're only as old as you think you are!" are slowly becoming the mottos for an optimistic trend for successful aging (Moody, 2002). However, Moody (2002) cautions such sentiments should not be based on denial of real losses in functioning in the last stage of life. Moody (2002) also suggested that successful aging should involve the psychological side of aging, including self-concept, social relationships, and the growth of cognitive processes.

1.5 Research Objectives

Rix (2001) found that the increment of life expectancy and the existence of a pension system (which faces stock-market risk) increase the number of workers over the age of 55 in the labor force. Based on the population survey in 1998, the median age of coal mine workers was the highest among all types of mines, reaching 45.2 years. This was followed by metal mine workers with a median age of 41.3 years, oil and gas workers with a median age of 41.1 years, and nonmetal mines with a median age of 39.1 years (Fotta and Bockosh, 2000). The median age of the overall mining workforce in 1998 was 41.2 years compared to 38.7 years for the entire labor force (Fotta and Bockosh, 2000).

Mining is an industry that has many hazardous jobs; the average annual mine operator fatality rate is 28.5 per 100,000 workers (U.S. Department of Labor and Mine, 2004). Since 1986, the U.S. Bureau of Mines has conducted surveys on the demographics of mine workers. This survey is done in order to provide information about the population at risk. This can help further research and study to pinpoint the segments of the mining population that are the most vulnerable to injury and illness (Butani, 1988). 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 time to recover after each accident, and to suffer a higher rate of fatality (Vernon and Bedford, 1928).

1.6 Hypotheses

Given that in mining, median age of workers is increasing, this research will test the following hypotheses using the data of fatalities in metal and non-metal mines between 2002 and 2006:

1) Older workers with the least experience (less than 1 year of experience) will have the highest fatality rates.
2) Workers working in small mines will have the highest fatality rates.

Chapter 2

Literature Review

2.1 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. 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 and 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 influence. Aging workers are defined by Stagner (1995) based on social and individual perceptions. Psychosocial definitions on aging workers are still not widely studied and many important questions about this view - such as how we know when workers perceived themselves to be old or how the society perceived them to be old are still unanswered. 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 down 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 in tasks that required rapid cognitive processing.

There are not 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 thesis 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).

2.2 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 than 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 lesser 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. This intelligence on the hand tends to increase with the aging process.

The process of aging is associated with the decline in homeostasis and functional loss (Coordt et al., 1995). 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 patters. They might take longer time to recover from injury (Hansson, DeKoekkoek, Neece and Patterson, 1997; Haight, 2003).

Physical strengths also decline with age (Warr, 1994; A.A. Sterns, Sterns and Hollis, 1996; Haight, 2003). Bones become lighter and brittle while lean muscle mass decreases and fat levels increase. Pscyhomotor ability to react with 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 to locate 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 quoted the decremental theory of aging based on previous research. 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 capabilities 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. Bolch (2000) found that aging workers received fewer training opportunities than younger workers.

2.3 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 age 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) tested two null hypotheses: 1) the proportion of works in each age group was similar to the proportion of injuries in the same age group; and 2) the proportion of workers in each experience group was the same as the proportion of injuries for the same group. Based on the result obtained from the chi-squared test, Butani (1988) rejected both null hypotheses. Butani (1988) also 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 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 and broken stone workers at $4,024 and oil and gas field service workers at $3,551. Iron ore mining workers and Copper ore mining 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 the 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 in mine 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 restaurant 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 fatalities per 100,000 workers but if the number of employees was used instead, the fatality rate dropped to 14 fatalities 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 fatalities 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 State 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 Bockosh (2000) found that the annual percentage of injured workers in metal and non-metal mine 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 with a mean r of 0.06.

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 equipments 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.

2.4 Conclusion

Based on the literature review, we can conclude that mining has very high fatality rate (Toscano and Windau, 1993; Ruser, 1998; Kisner and Pratt, 1994) and there are differences between fatality rate and cost per worker in metal and non-metal mines and other type of mines (Leigh et al., 1997). Older workers are also found to have higher fatality rate than younger workers (Castillo and Malit, 1997; Kisner and Pratt, 1994; Fotta and Bockash, 2000). Workers with the least experience have higher fatality rate than workers with more than 15 years of experience (Butani, 1988; Chi and Wu, 1997; Kecojevic et al., 2007; Groves et al., 2007). Based on this literature review, older workers with the least experience and workers in small mines would represent the highest fatality in metal and non-metal mines between 2002 and 2006. This will be the hypotheses of this thesis.

Chapter 3

Method

3.1 Introduction

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 2.

Table 2: Description of the factors (Qiu, B.J., 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 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 3 and Table 4. 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 also shown in Table 3 and Table 4. **Size** is divided into three categories and not into five categories in order to reduce the number of combinations for the factors.

Table 3: Categorical Factors and Their Descriptions (Qiu, B.J., 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

Table 4: Detailed Description of the Factors (Qiu, B.J., 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

The dataset collected from the Mining and Health Administration (MSHA) website is available in Appendix A (Qiu, B.J., 2008). Each row recorded the fatalities based on the combination of three factors: for example, the second row showed that there were, in total, 5 workers killed (2 in 2003, and 3 in 2002). These workers were categorized as Age Group 1, Experience Group 2, and Size Group 1. This means the workers were very young (17-24 years old), worked in the small mine(less than 50 employees) and had experience above between 1 to 5 years.

3.2 Method used

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

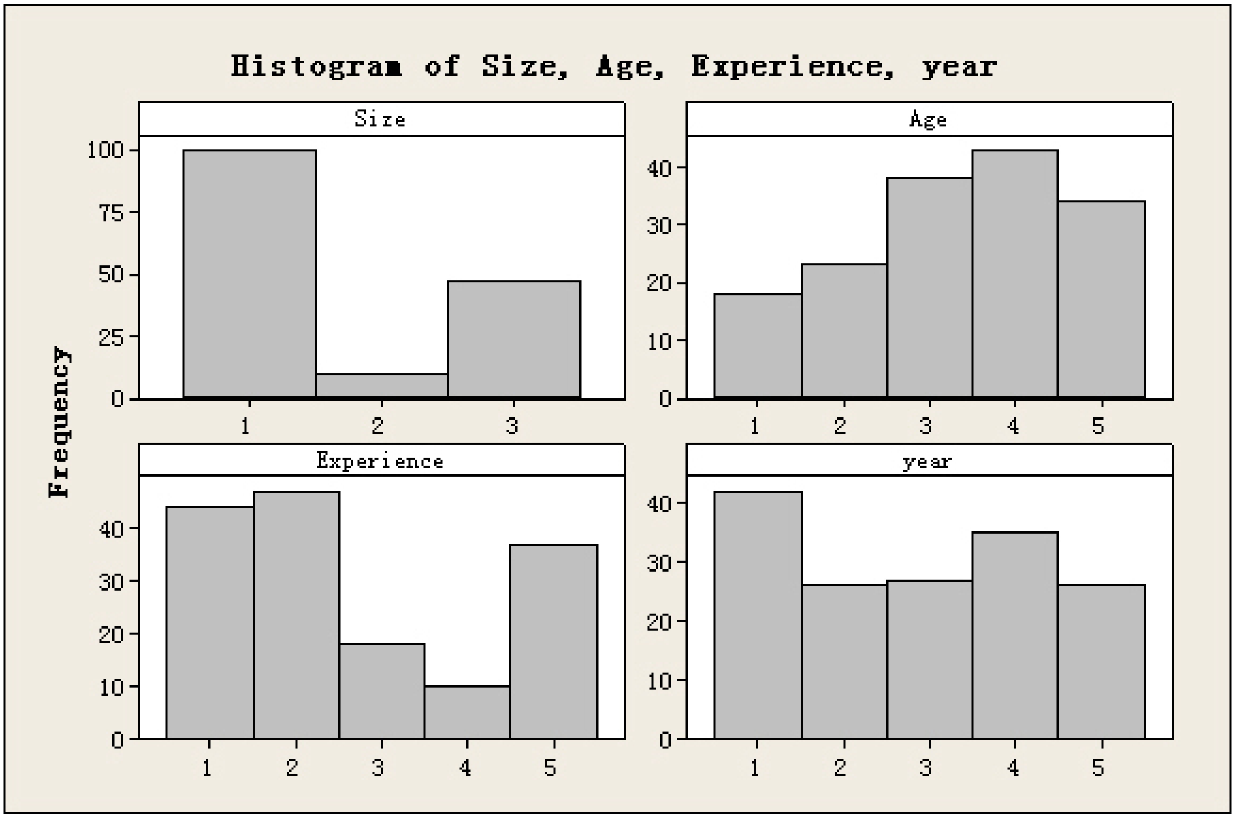

Figure 1: Histograms of Size, Age, Experience and Year and the Frequency of Fatalities.

For the mine Size, most of the fatalities happened in small mines while medium size mines have the lowest number of fatalities. For the Age factor - Age Group 4 (45-54 years) represents the highest number of fatalities while Age Group 1 (17-24 years) represents the lowest number of fatalities. For the Experience factor – Experience Group 2 (1-5 years) has slightly higher fatalities than Experience Group 1 (less than 1 year of experience).

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, B.J., 2008). Apart from being independent to each other, the responses in ANOVA must also be normally distributed (Qiu, B.J., 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 highly correlated. This means Age and Experience are not independent to each other and therefore must not be included in the ANOVA model (Qiu, B.J., 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 and are shown in Figure 3. The P-value of the Chi-Square test in Figure 4 is 0.264. This indicates that Size and Age are independent to each other.

Tabulated statistics: Size, Age

Using frequencies in Total

Rows: Size Columns: Age

	1	2	3	4	5	All
1	13	11	26	26	24	100
2	0	2	2	1	4	9
3	5	10	10	16	6	47
All	18	23	38	43	34	156

Cell Contents: Count

Pearson Chi-Square = 10.008, DF = 8, **P-Value = 0.264**

Likelihood Ratio Chi-Square = 10.947, DF = 8, P-Value = 0.205

* NOTE * 5 cells with expected counts less than 5

Figure 3: Tabulated Statistics for Size, Age

The same is repeated for Size and Experience. Figure 4 shows the results. Figure 4 shows that as Experience increases, the number of deaths tends to decrease; except in Experience = 5. When the Size is small, the number of deaths is high; when the Size is large, the number of deaths is relatively low. But for Size=3, the number of deaths is much bigger than the number of deaths in Size=2.

Tabulated statistics: Size, Experience

Using frequencies in Total

Rows: Size   Columns: Experience

	1	2	3	4	5	All
1	29	27	13	5	26	100
2	1	3	1	1	3	9
3	14	17	4	4	8	47
All	44	47	18	10	37	156

Cell Contents: Count

Pearson Chi-Square = 4.885, DF = 8

Likelihood Ratio Chi-Square = 5.162, DF = 8

* WARNING * 1 cells with expected counts less than 1

* WARNING * Chi-Square approximation probably invalid

* NOTE * 6 cells with expected counts less than 5

Figure 4: Tabulated Statistics for Size, Experience

3.3 ANOVA

Since Age and Experience are highly correlated, only 2-way interactions were included in the ANOVA and the 3-way interactions were left in the error term (Qiu, B.J., 2008). Figure 5 shows the results and Figure 6 shows the residual plots.

General Linear Model: Total versus Size, Experience, Age

Factor	Type	Levels	Values
Size	fixed	3	1, 2, 3
Experience	fixed	5	1, 2, 3, 4, 5
Age	fixed	5	1, 2, 3, 4, 5

Analysis of Variance for Total, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Size	2	167.120	167.12	83.560	29.05	0.000
Experience	4	71.387	71.387	17.847	6.20	0.001
Age	4	28.987	28.987	7.247	2.52	0.061
Size*Experience	8	45.413	45.413	5.677	1.97	0.083
Size*Age	8	31.413	31.413	3.927	1.37	0.249
Experience*Age	16	101.147	101.147	6.322	2.20	0.028
Error	32	92.053	92.053	2.877		
Total	74	537.520				

S = 1.69607   R-Sq = 82.87%   R-Sq(adj) = 60.40%

Unusual Observations for Total

Obs	Total	Fit	SE Fit	Residual	St Resid
1	8.0000	5.6800	1.2842	2.3200	2.09 R
25	13.0000	9.6800	1.2842	3.3200	3.00 R

R denotes an observation with a large standardized residual.

Figure 5: Results of 3-way ANOVA.

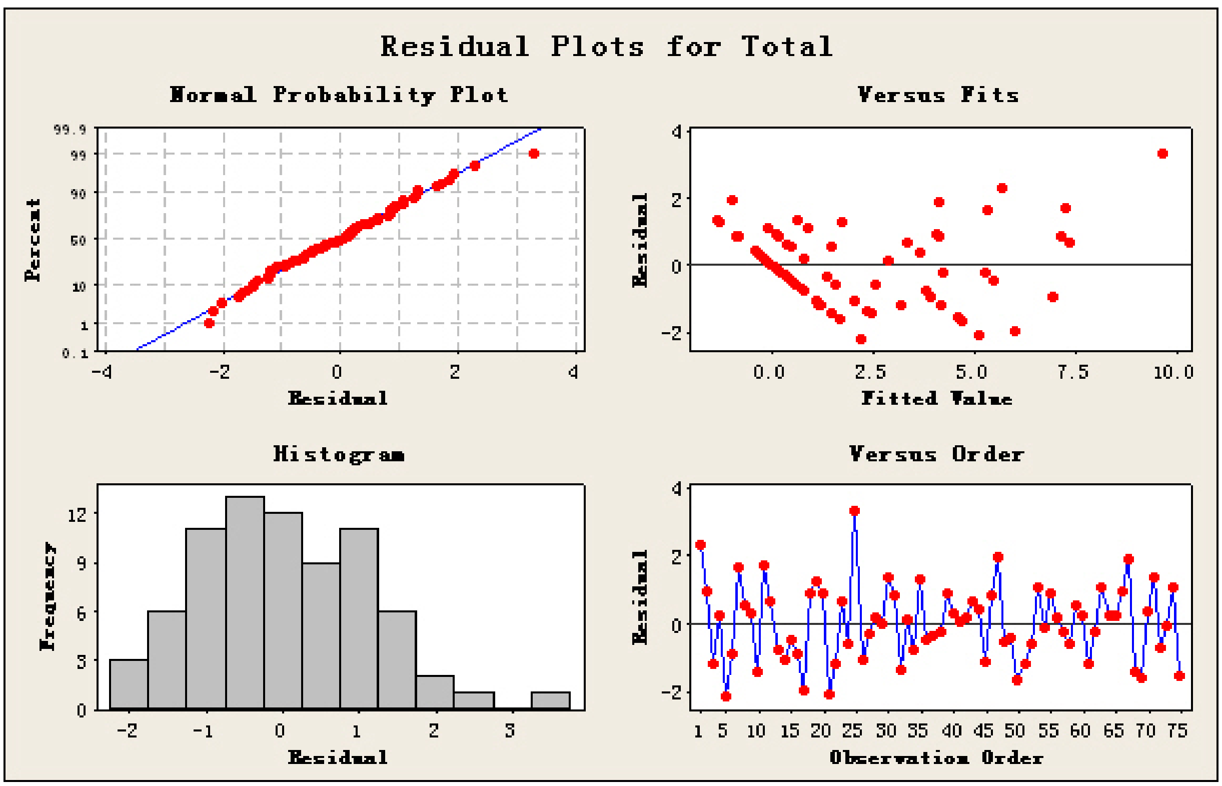

Figure 6: Residual Plots for the 3-way Interactions.

Figure 5 shows that Size, Experience and the interaction between Experience and Age are significant (P-Value is less than 0.05). The residual plot at the left upper corner of Figure 6 is the normality plot of the residuals. It is approximately linear with slope equal to 1 which indicates that the residuals approximately follow a normal distribution (Qiu, B.J., 2008). This histogram also shows that the distribution of the residuals is nearly bell-shaped and symmetric.

Based on the result obtained in Figure 5, the interaction between Experience and Age are studied using the Factor plots (Qiu, B.J., 2008). This Interaction plot is shown in Figure 7. Experience group 5 and Age group 5 have the highest interaction mean.

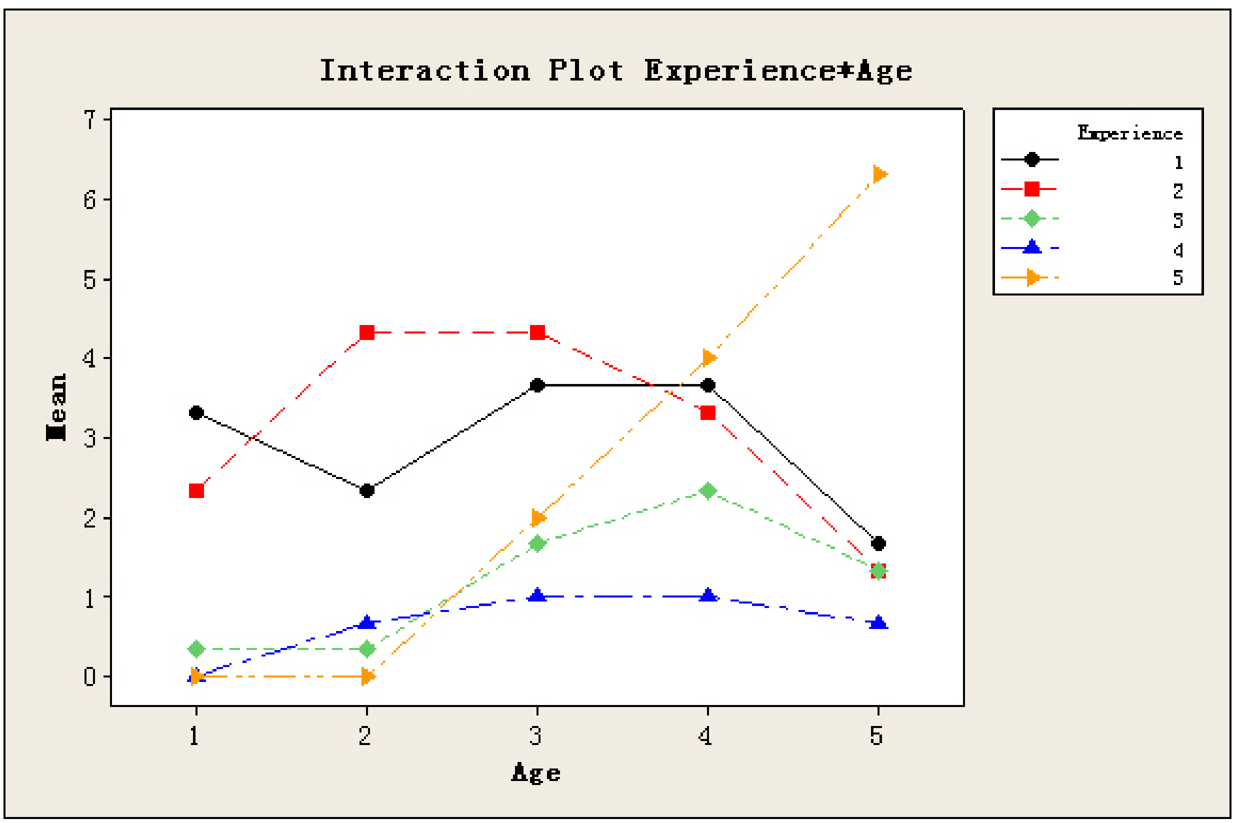

Figure 7: Interaction Experience*Age.

3.4 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 is to define a new variable based on Age and Experience (Qiu, B.J., 2008).

First, let's use the first method by leaving Age out of the ANOVA model and by only including Size and Experience (Qiu, B.J., 2008). The model is shown in Figure 8. The P-value for the interaction between Size and Experience without Age is 0.204, which is not significant. Furthermore, Figure 9 shows the residual plots for Figure 8 do not follow a normal distribution because the residuals become larger as the fitted values increase. In order to solve this problem, the ANOVA model is run using sqrtTotal, where the Total is squared. This leads to residual plots that follow a normal distribution as shown in Figure 10. The output of ANOVA is shown in Figure 11.

General Linear Model: Total versus Size, Experience

Factor	Type	Levels	Values
Size	fixed	3	1, 2, 3
Experience	fixed	5	1, 2, 3, 4, 5

Analysis of Variance for Total, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Size	2	167.120	167.120	83.560	19.77	0.000
Experience	4	71.387	71.387	17.847	4.22	0.004
Size*Experience	8	45.413	45.413	5.677	1.34	0.240
Error	60	253.600	253.600	4.227		
Total	74	537.520				

S = 2.05589 R-Sq = 52.82% R-Sq(adj) = 41.81%

Unusual Observations for Total

Obs	Total	Fit	SE Fit	Residual	St Resid
5	0.0000	5.2000	0.9194	-5.2000	-2.83 R
10	0.0000	5.2000	0.9194	-5.2000	-2.83 R
25	13.0000	5.2000	0.9194	7.8000	4.24 R

R denotes an observation with a large standardized residual.

Figure 8: Results for ANOVA (Size and Experience).

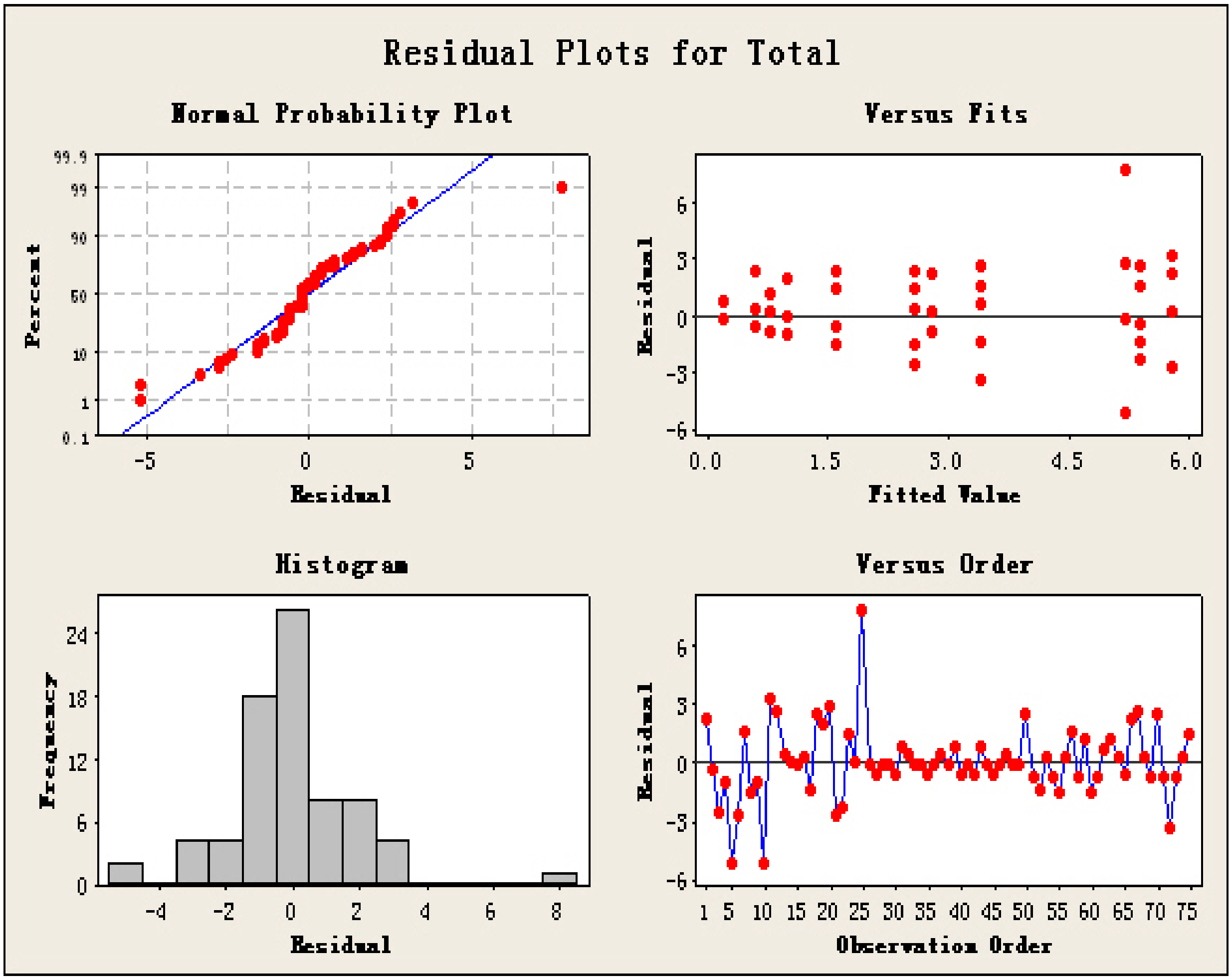

Figure 9: Residual Plots for Size and Experience.

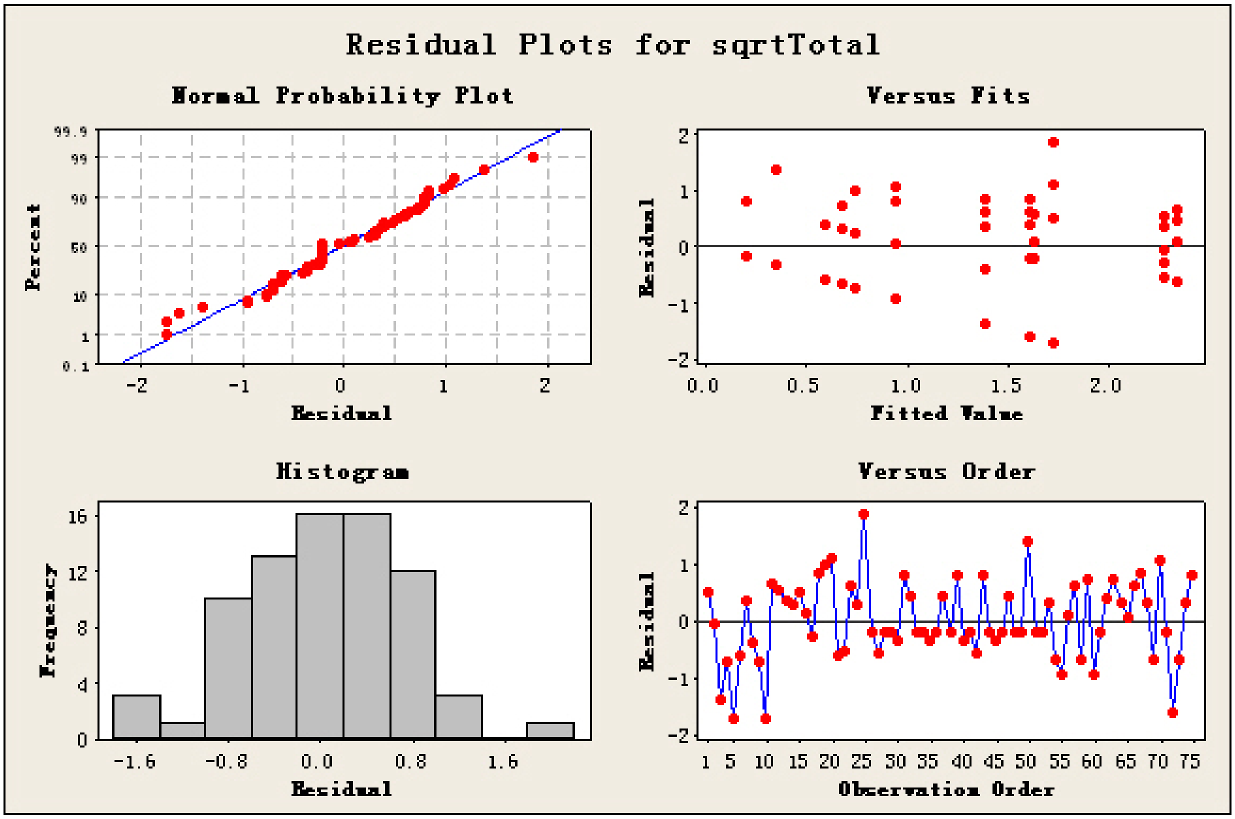

Figure 10: Residual Plots for Size and Experience using the sqrtTotal.

General Linear Model: sqrtTotal versus Size, Experience

Factor	Type	Levels	Values
Size	fixed	3	1, 2, 3
Experience	fixed	5	1, 2, 3, 4, 5

Analysis of Variance for sqrtTotal, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Size	2	24.4505	24.4505	12.2253	20.40	0.000
Experience	4	10.0269	10.0269	2.5067	4.18	0.005
Size*Experience	8	4.1110	4.1110	0.5139	0.86	0.557
Error	60	35.9635	35.9635	0.5994		

```
Total                 74   74.5519

S = 0.774204   R-Sq = 51.76%   R-Sq(adj) = 40.50%

Unusual Observations for sqrtTotal

Obs  sqrtTotal      Fit   SE Fit  Residual  St Resid

  3    0.00000  1.39362  0.34623  -1.39362     -2.01 R

  5    0.00000  1.73401  0.34623  -1.73401     -2.50 R

 10    0.00000  1.73401  0.34623  -1.73401     -2.50 R

 25    3.60555  1.73401  0.34623   1.87154      2.70 R

 50    1.73205  0.34641  0.34623   1.38564      2.00 R

 72    0.00000  1.61995  0.34623  -1.61995     -2.34 R

R denotes an observation with a large standardized residual.
```

Figure 11: Results for ANOVA Size and Experience using the sqrtTotal.

The interaction between Size*Experience in Figure 11 is not statistically significant but the P-values for both factors are small, so both Size and Experience are significant. The same can be done for Size, Age and Size*Age.

For the second method, a new variable is needed. This variable can be defined as AgeSubtractExperience (Qiu, B.J., 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

Method used to calculate **AgeSubtractExperience** is shown in Figure 12.

accidents1.MPJ ***

↓	C1 Size	C2 Age	C3 Experience	C4 y2006	C5 y2005	C6 y2004	C7 y2003	C8 y2002	C9 Total	C10 AgeSubtractExperience
39	2	3	4	1	0	0	0	0	1	-1
40	2	3	5	0	0	0	0	0	0	-2
41	2	4	1	0	0	0	0	0	0	2
42	2	4	2	0	0	0	0	0	0	2
43	2	4	3	0	1	0	0	0	1	1
44	2	4	4	0	0	0	0	0	0	0
45	2	4	5	0	0	0	0	0	0	-1
46	2	5	1	0	0	0	0	0	0	2
47	2	5	2	0	0	1	0	0	1	2
48	2	5	3	0	0	0	0	0	0	2
49	2	5	4	0	0	0	0	0	0	1
50	2	5	5	0	0	1	1	1	3	0
51	3	1	1	0	1	1	0	0	2	0
52	3	1	2	1	0	1	0	0	2	-1
53	3	1	3	0	0	0	0	1	1	-2
54	3	1	4	0	0	0	0	0	0	-2
55	3	1	5	0	0	0	0	0	0	-2
56	3	2	1	0	2	0	1	0	3	1
57	3	2	2	1	0	0	1	3	5	0

Figure 12: New Data (Qiu, B.J., 2008).

Tabulated statistics of AgeSubtractExperience and Age are shown in Figure 13.

Tabulated statistics: AgeSubtractExperience, Age

Using frequencies in Total

Rows: AgeSubtractExperience   Columns: Age

	1	2	3	4	5	All
-2	1	2	6	0	0	9
-1	7	1	3	12	0	23
0	10	13	5	3	19	50
1	0	7	13	7	2	29
2	0	0	11	21	13	45
All	18	23	38	43	34	156

Cell Contents: Count

Pearson Chi-Square = 89.539, DF = 16, P-Value = 0.000

Likelihood Ratio Chi-Square = 110.989, DF = 16, P-Value = 0.000

* NOTE * 9 cells with expected counts less than 5

Figure 13: Tabulated Statistics of AgeSubtractExperience, Age.

Age and AgeSubtractExperience are highly correlated.   So in the following ANOVA; only Size, AgeSubtractExperience and their interactions are tested. Figures 14, 15 and 16 show the residuals plots, results and main effects plots.

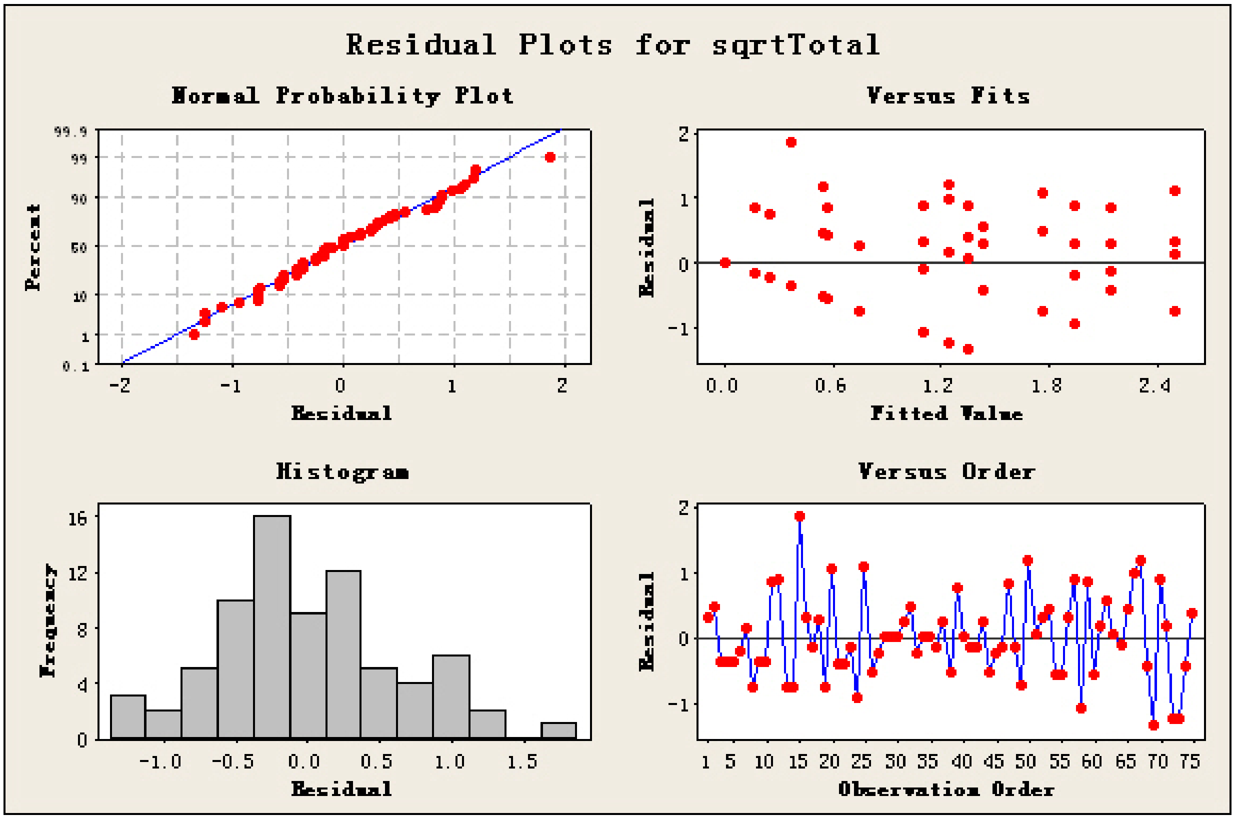

Figure 14: Residual Plots for AgeSubtractExperience and Age.

General Linear Model: sqrtTotal versus Size, AgeSubtractExperience

Factor	Type	Levels	Values
Size	fixed	3	1, 2, 3
AgeSubtractExperience	fixed	5	-2, -1, 0, 1, 2

Analysis of Variance for sqrtTotal, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Size	2	24.4505	24.1060	12.0530	23.79	0.000
AgeSubtractExperience	4	14.0556	14.0556	3.5139	6.94	0.000
Size*AgeSubtractExperience	8	5.6518	5.6518	0.7065	1.39	0.217
Error	60	30.3940	30.3940	0.5066		
Total	74	74.5519				

S = 0.711735 R-Sq = 59.23% R-Sq(adj) = 49.72%

Unusual Observations for sqrtTotal

Obs	sqrtTotal	Fit	SE Fit	Residual	St Resid
15	2.23607	0.37268	0.29056	1.86339	2.87 R
69	0.00000	1.35931	0.31830	-1.35931	-2.14 R

R denotes an observation with a large standardized residual.

Figure 15: Results of ANOVA for AgeSubtractExperience and Age.

Since the interaction is not significant, we conclude the significance of main effects by their P-values. Only **AgeSubtractExperience** and **Size** are both significant.

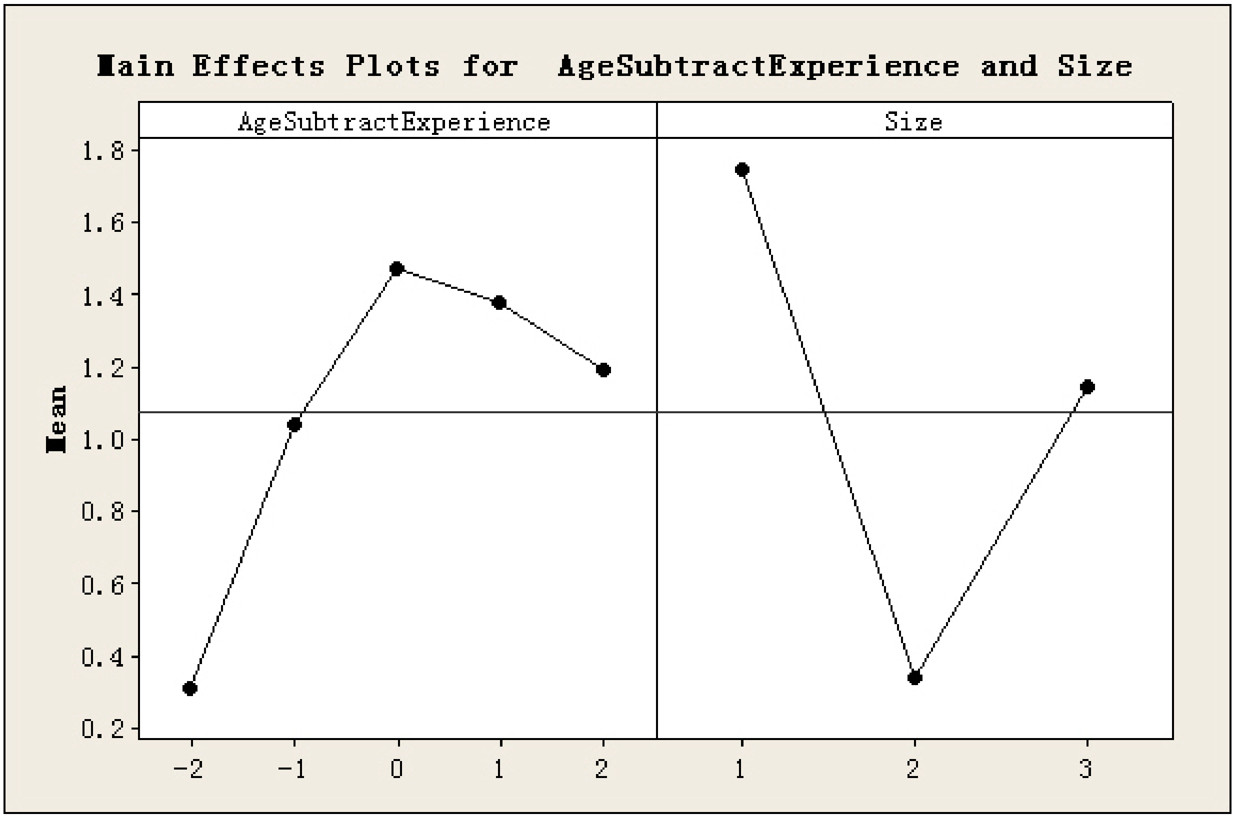

Figure 16: Main Effects Plots.

In Figure 16, 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.

3.5 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 Group 4 and 5 are included in the new factor plots. By including workers in Age group 4 – the age for defining aging workers has been reduced to 45. The result is shown in Figure 17. For this case, the AgeSubstractExperience is defined as follow:

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

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

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

If (Age – Experience = 1) AgeSubtractExperience=1

If (Age – Experience >1) AgeSubtractExperience=1

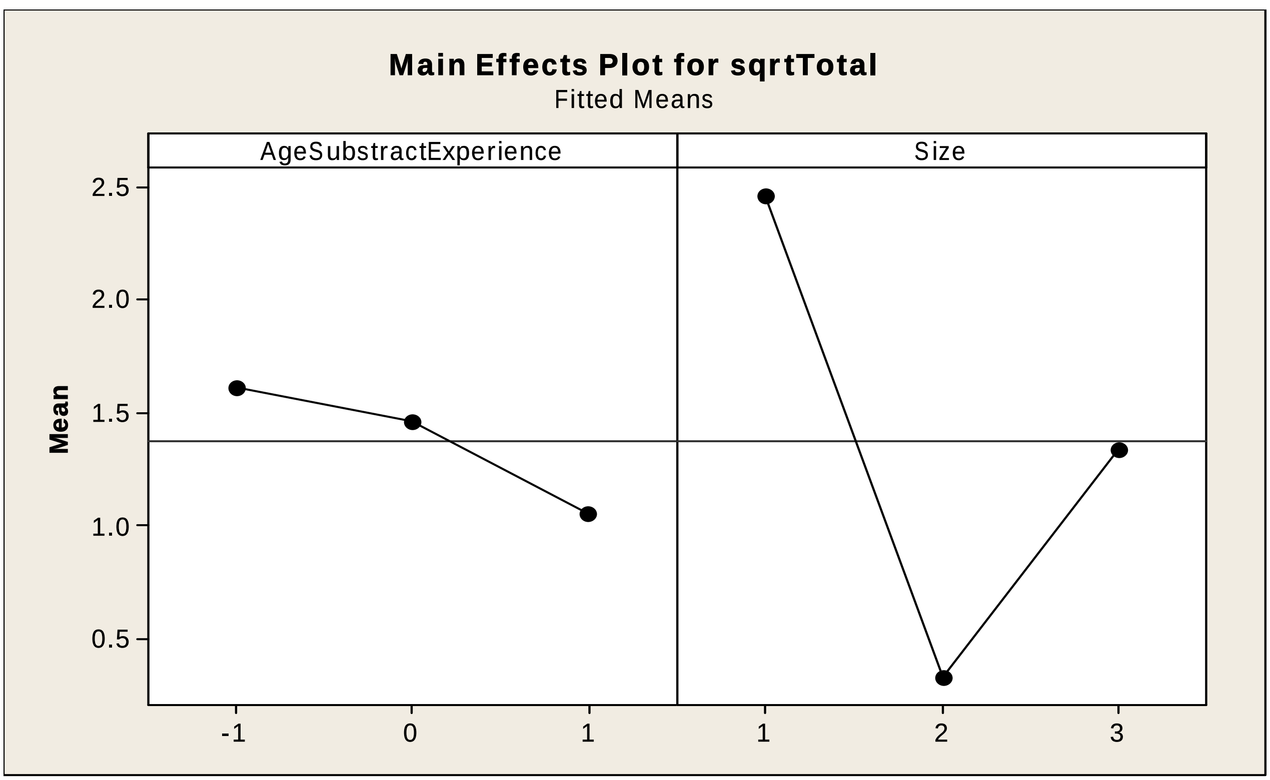

Figure 17: Main Effect Plots when **Age** groups 1, 2 and 3 are removed.

Figure 17 shows that workers in Age – Experience = -1 and Age – Experience < -1 have higher mean for the main effect plots. By including Age group 3, 4 and 5 and defining AgeSubstractExperience as follow, result shown in Figure 18 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

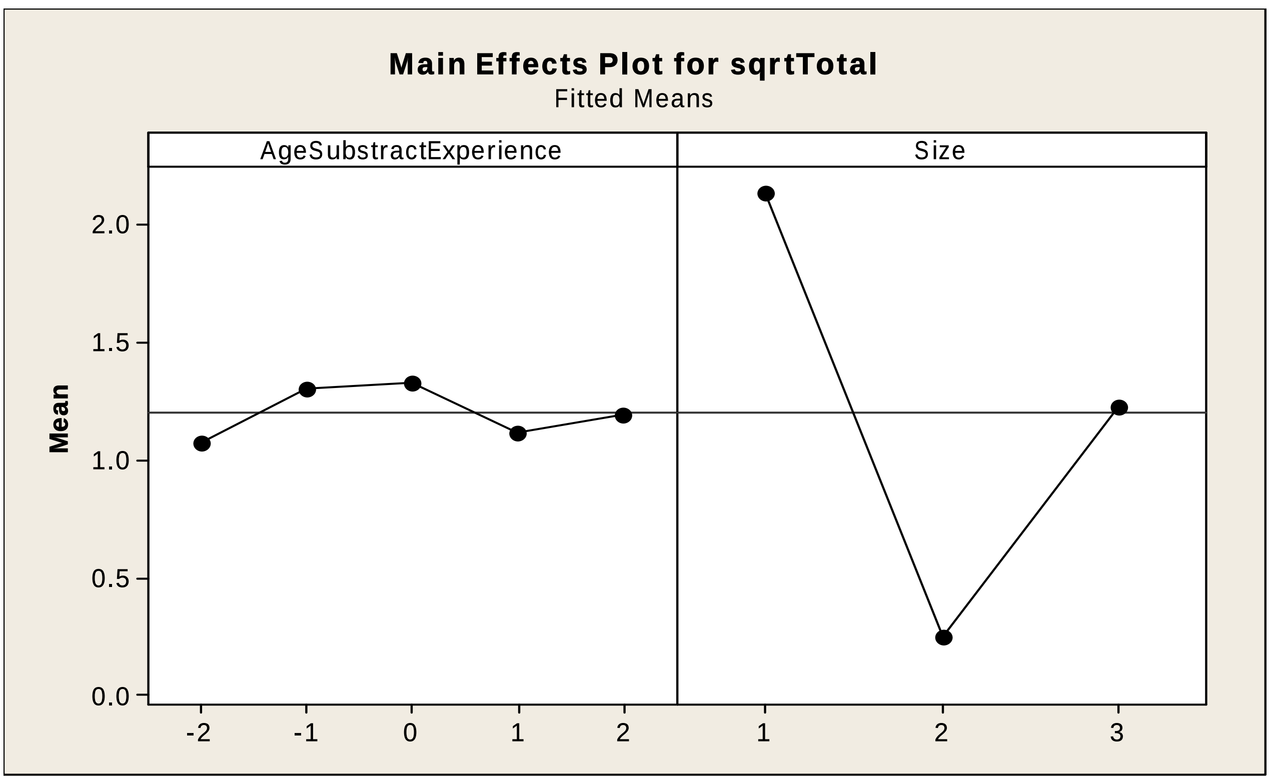

Figure 18: Main Effect Plots when Age groups 1 and 2 are removed.

3.6 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) X 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.

Table 5 shows the number of workers (in thousands) that are working in metal and non-metal mines and Table 6 shows the number of fatalities in metal and non-metal mines based on the five different Age groups.

Table 5: Total number of workers (in thousands) in metal and non-metal mines based on Age.

Year	17-24	25-34	35-44	45-54	>55
2002	6	19	37	35	16
2003	8	27	40	39	19
2004	7	22	40	40	17
2005	8	18	35	32	25
2006	9	30	33	41	28
Total	38	116	185	187	105

Table 6: Number of fatalities in metal and non-metal mines based on Age group.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	5	6	8	16	7
2003	2	3	10	7	4
2004	3	3	8	6	7
2005	4	9	5	9	8
2006	4	2	7	5	8
Total	18	23	38	43	34

Based on Table 5 and 6, the fatalities per 100,000 workers can be calculated using equation 1. These fatalities per 100,000 workers are shown in Table 7.

Table 7: Fatalities per 100,000 workers.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	83.33	31.58	21.62	45.71	43.75
2003	25.00	11.11	25.00	17.95	21.06
2004	42.86	13.64	20.00	15.00	41.18
2005	50.00	50.00	14.29	28.13	32.00
2006	44.44	6.67	21.21	12.19	28.57
Total	47.37	19.83	20.54	22.99	32.38

3.7 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)

Table 8 shows the percentage of workers in metal and non-metal mines from 2002-2006 based on the five Age groups and Table 9 shows percentage of fatalities in metal and non-metal mines from 2002-2006 based on the five Age groups.

Table 8: Percentage of workers in metal and non-metal mines from 2002-2006 based on age group.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	5.31	16.81	32.74	30.97	14.16
2003	6.02	20.30	30.08	29.32	14.29
2004	5.56	17.46	31.75	31.75	13.49
2005	6.78	15.25	29.66	27.12	21.19
2006	6.38	21.28	23.40	29.08	19.86
Total	6.02	18.38	29.32	29.64	16.64

Table 9: Percentage of fatalities in metal and non-metal mines from 2002-2006 based on age group.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	11.90	14.29	19.05	38.10	16.67
2003	7.69	11.54	38.46	26.92	15.38
2004	11.11	11.11	29.63	22.22	25.93
2005	11.43	25.71	14.29	25.71	22.86
2006	15.38	7.69	26.92	19.23	30.77
Total	11.54	14.74	24.36	27.56	21.79

By using the percentage in both Table 8 and Table 9 and equation 2, the risk index can be calculated. This risk index is shown in Table 10.

Table 10: Risk Index for metal and non-metal mines from 2002-2006 based on age group.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	2.24	0.85	0.58	1.23	1.18
2003	1.28	0.57	1.28	0.92	1.08
2004	2.00	0.64	0.93	0.70	1.92
2005	1.69	1.69	0.48	0.95	1.08
2006	2.41	0.36	1.15	0.66	1.55
Total	1.92	0.80	0.83	0.93	1.31

3.8 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.

This class of fatality is then categorized based on age group, years of experience and the size of mine. Table 11 shows the class of fatality from 2002 to 2006.

Table 11: Number of fatalities and the classes of death.

Class	2002	2003	2004	2005	2006
Falling Material	2	3	4	3	6
Machinery	13	8	6	10	4
Electrical	2	2	1	2	5
Powered Haulage	15	6	7	16	7
Fall of Highway	1	0	1	0	1
Fall of Person	2	3	6	3	3
Explosion	1	1	1	1	0
Hoisting	1	1	0	0	0
Other	5	2	1	0	0

Chapter 4

Summary of Results

4.1 Introduction

In Figure 19, for the main effect of Size, most of the fatalities in metal and non-metal mine happened in small mines (with 1-50 employees), followed by large mine (more than 100 employees. The smallest number of fatalities occurred in medium size mine (between 51-100 employees).

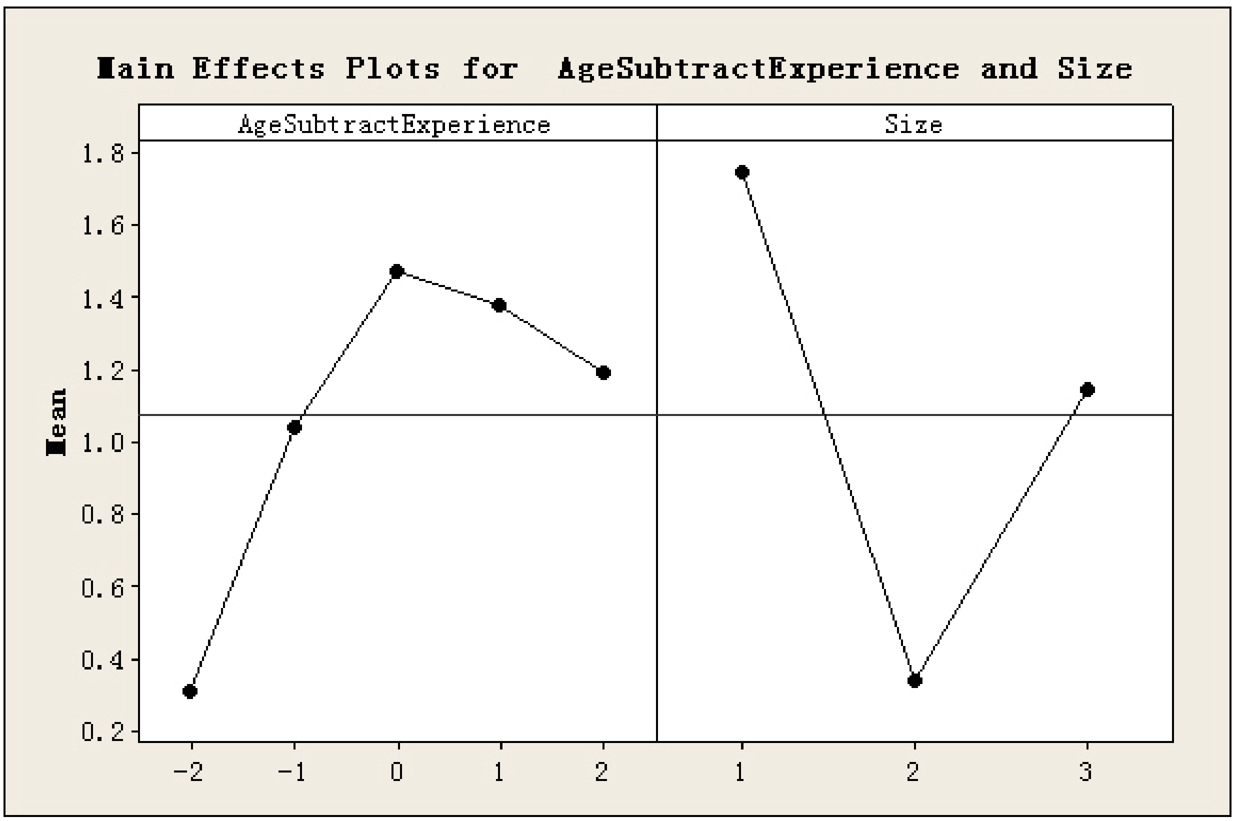

Figure 19: Main Effects Plots.

Main effect plots for AgeSubstractExperience show that workers with Age>Experience (AgeSubtractExperience>0) have higher fatality rate than Age<Experience

(AgeSubtractExperience<0), and workers with Age=Experience (AgeSubtractExperience=0) have the highest fatality rate. But the main effect plots in Figure 20 include confounding factors (workers in Age groups 1 and 2 cannot belong to Experience group 4 and 5). It can be inferred from figure 19 that workers in the same Age and Experience groups have the mean in main effect plots.

To overcome the confounding factors – only Age groups 4 and 5 are included in the same analysis. The result is shown is Figure 20. The means show that Age< Experience has higher fatality rates than Age=Experience and Age> Experience. This contradicts the results obtained in Figure 20.

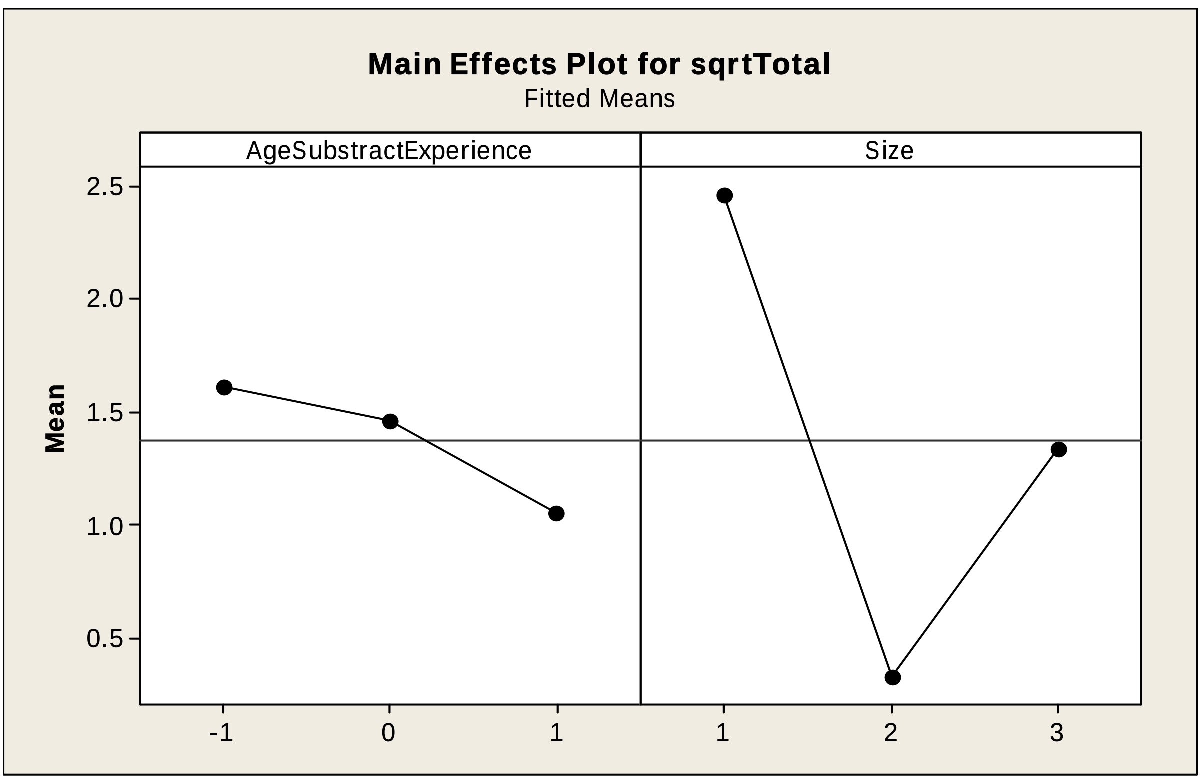

Figure 20: Main Effects Plots.

A different approach that includes Age groups 3, 4 and 5 is shown in Figure 21 that shows (Age – Experience = -1) and when (Age-Experience= 0) have the highest mean effects but (Age –Experience < -1) has the lowest main effects.

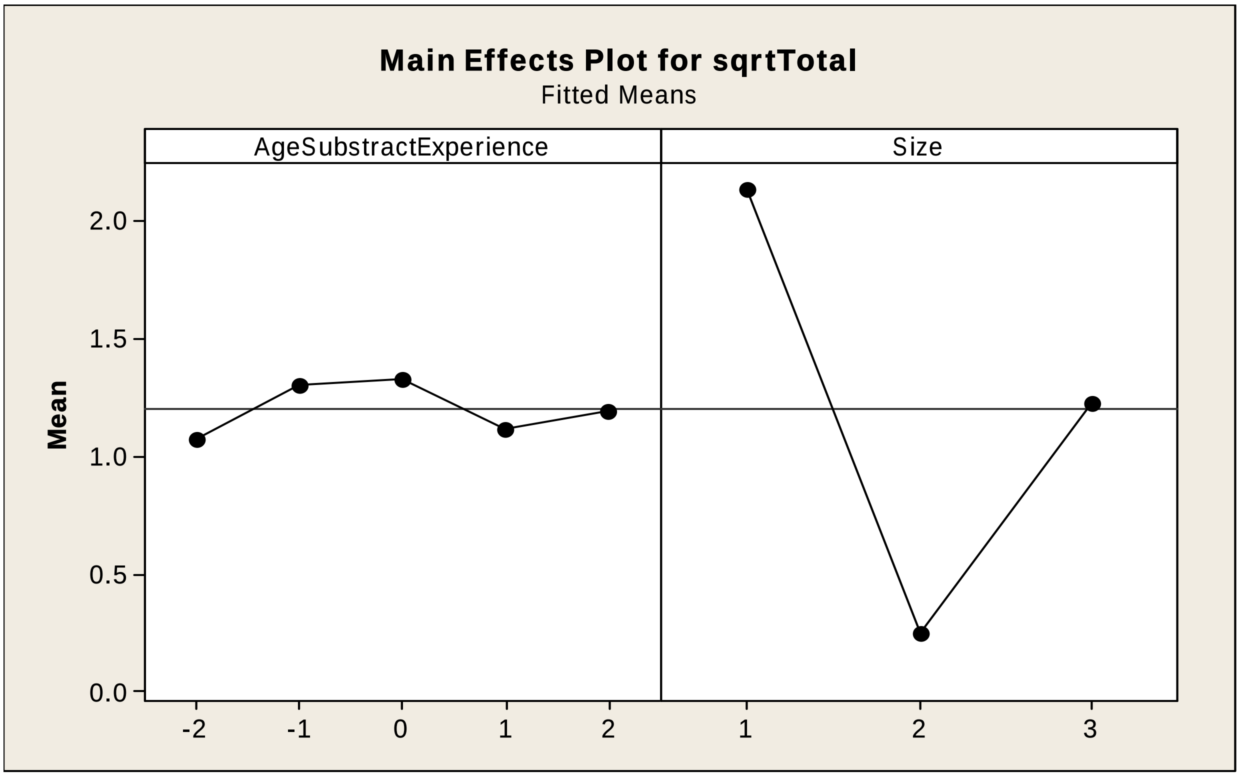

Figure 21: Main Effect Plots when Age groups 1 and 2 were removed.

4.2 Fatalities per 100,000 workers

Table 7 shows that workers between the ages of 17-24 had the highest fatalities per 100,000 workers (47.37), followed by workers over the age of 55 (32.28 fatalities per 100,000 workers). Workers between the ages of 25-34 had the lowest fatalities per 100,000 workers (19.38). Figure 22 shows the trend of the fatalities per 100,000 workers based on the Age group.

Table 7: Fatalities per 100,000 workers.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	83.33	31.58	21.62	45.71	43.75
2003	25.00	11.11	25.00	17.95	21.06
2004	42.86	13.64	20.00	15.00	41.18
2005	50.00	50.00	14.29	28.13	32.00
2006	44.44	6.67	21.21	12.19	28.57
Total	47.37	19.83	20.54	22.99	32.38

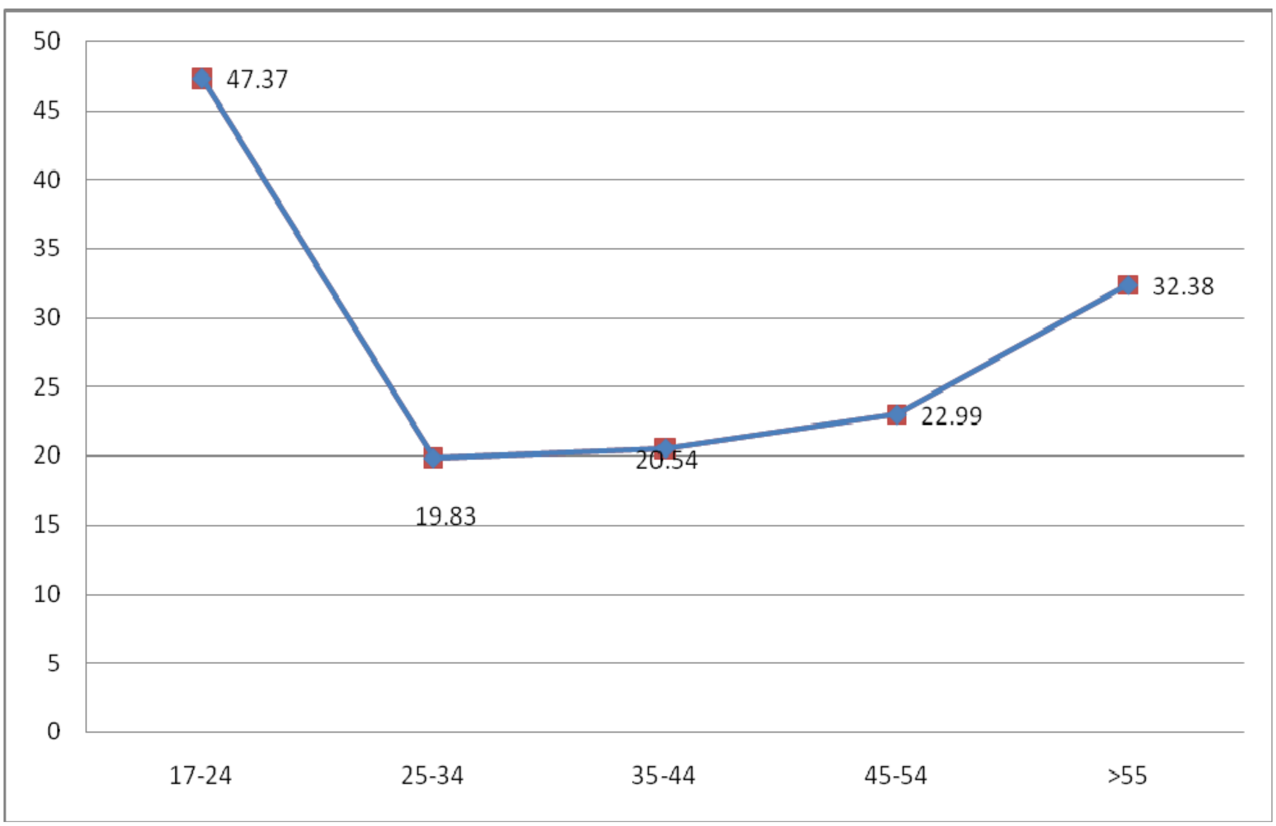

Figure 22: Fatalities per 100,000 workers based on age group in metal and non-metal mines from 2002 to 2006.

4.3 Risk Index

Table 10 shows the risk index based on the age group. Risk index above 1.00 indicates greater risk while risk index below 1.00 indicates smaller risk.

Table 10: Risk Index for metal and non-metal mines from 2002-2006 based on age group.

Year/Age	17-24	25-34	35-44	45-54	>55
2002	2.24	0.85	0.58	1.23	1.18
2003	1.28	0.57	1.28	0.92	1.08
2004	2.00	0.64	0.93	0.70	1.92
2005	1.69	1.69	0.48	0.95	1.08
2006	2.41	0.36	1.15	0.66	1.55
Total	1.92	0.80	0.83	0.93	1.31

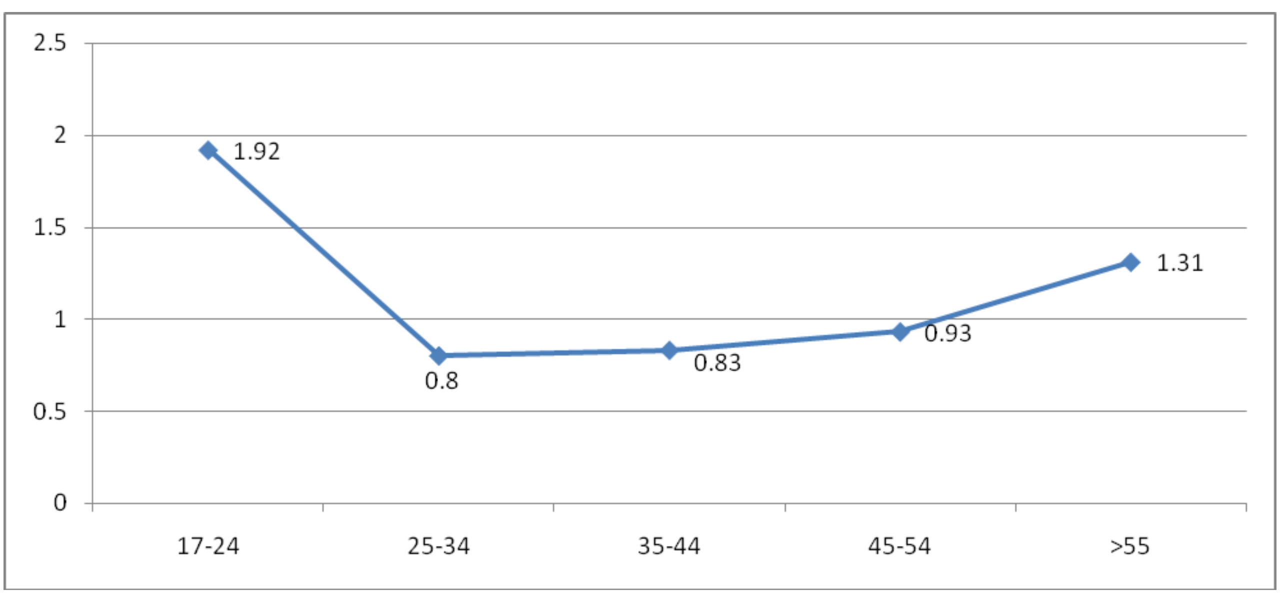

Figure 23: The risk index based on age groups in metal and non-metal mines from 2002 to 2006.

Based on Table 10 and Figure 23, the risk index for workers between the ages of 17-24 is 1.92. This indicates this age group had the greatest risk, followed by workers over the age of 55 with a risk index of 1.31. Workers between the age of 25-34 had the smallest risk index (0.80) compared to the other age groups.

4.4 Classes of Accidents

Figure 24 shows the numbers of death based on class of accident in metal and non-metal mines from 2002 to 2006.

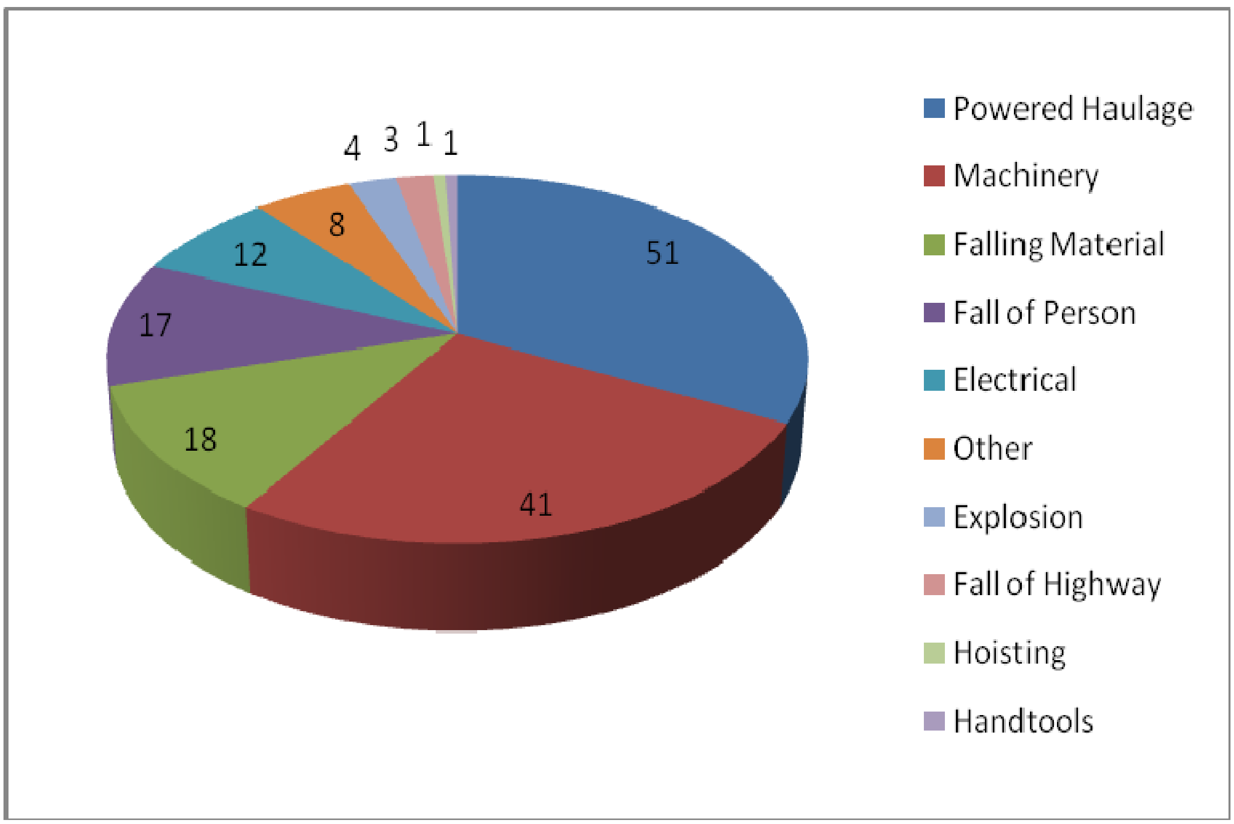

Figure 24: Numbers of death based on class of accident in metal and non-metal mines from 2002-2006.

Powered haulage recorded the highest number of fatalities (51 deaths), followed by machinery (41 deaths),falling material (18 deaths), fall of person (17 deaths) and electrical (12 deaths).Hoisting and handtools recorded 1 case of death each.

4.5 Powered Haulage Fatalities Breakdown

Figure 25 shows the percentage of age groups involved in fatalities with powered haulage. Workers over the age of 55 represented a quarter of the fatalities involving powered haulage. This is followed by the age group 45-54 (21%), age group 17-24 (20%), age group 35-44 (18%) and age group 25-24 (16%).

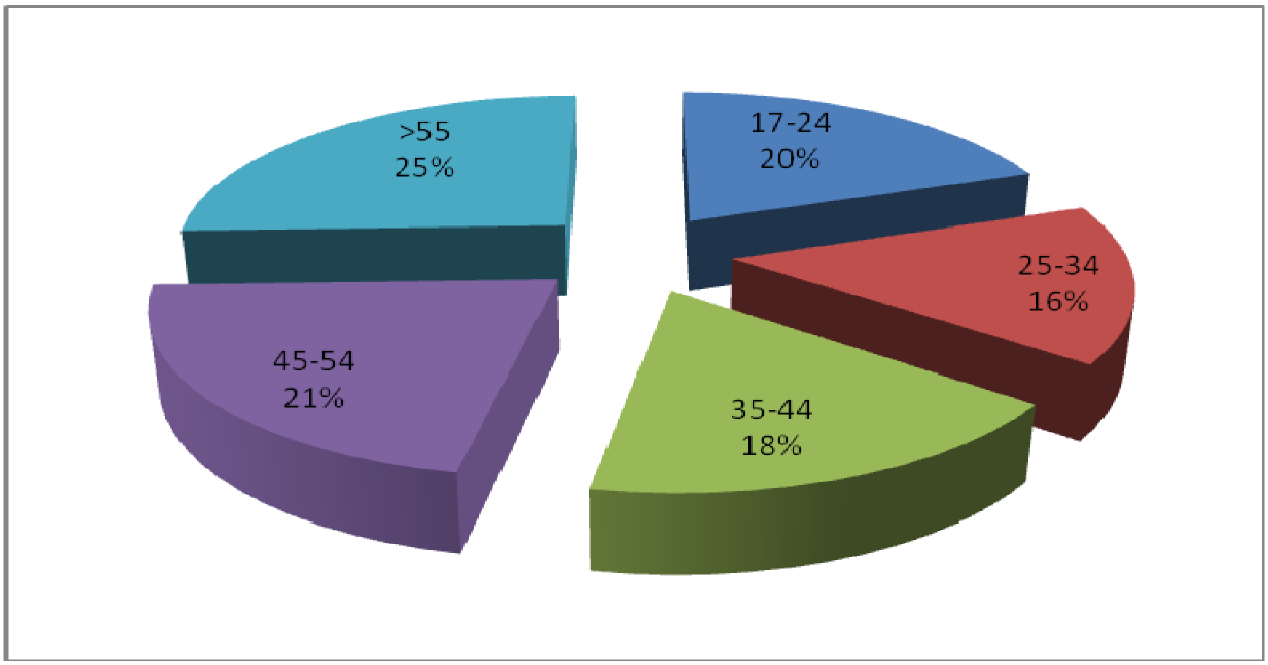

Figure 25: Percentage of workers based on age group involved in power haulage fatalities.

Figure 26 shows the percentage of years of job experience groups involved in fatalities with powered haulage. Workers with 1-5 years of experience recorded 35% of the fatalities involving powered haulage, followed closely by workers with less than 1 year of experience

(33%). Workers with more than 15 years of experience had 15% of the total number of fatalities involving powered haulage.

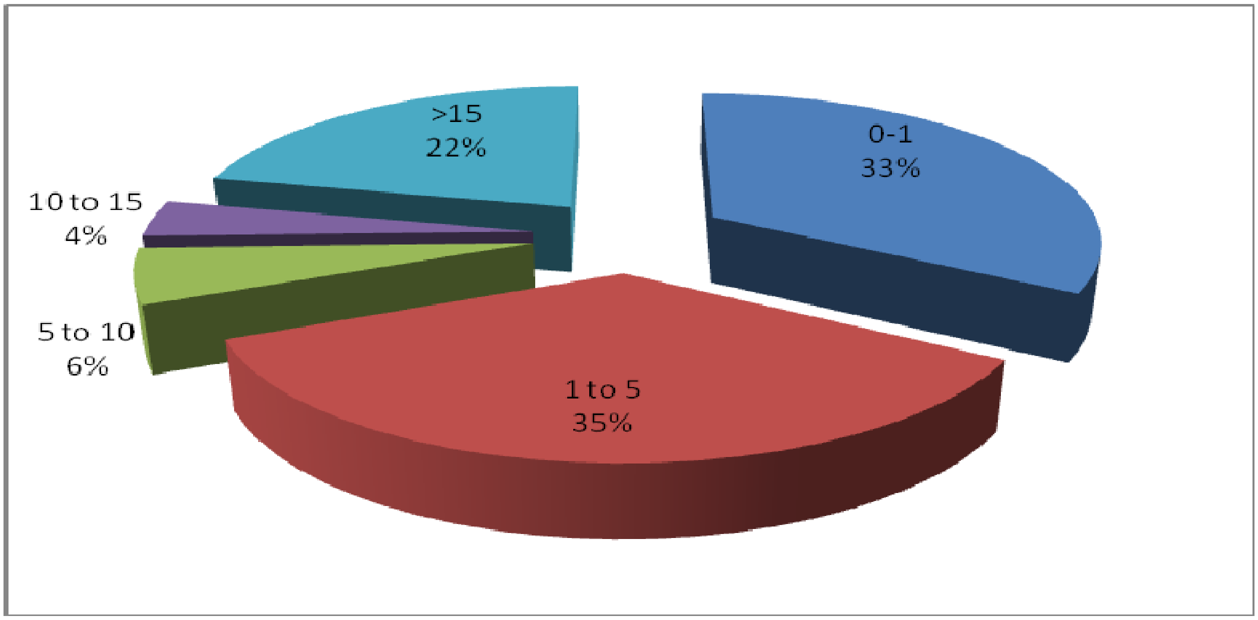

Figure 26: Percentage of workers based on years of job experience involved in power haulage fatalities.

Figure 27 shows that almost three quarter of the fatalities involving powered haulage occurred in mines with 1-50 employees. 22% of the fatalities involving powered haulage took place in mines with more than 100 employees.

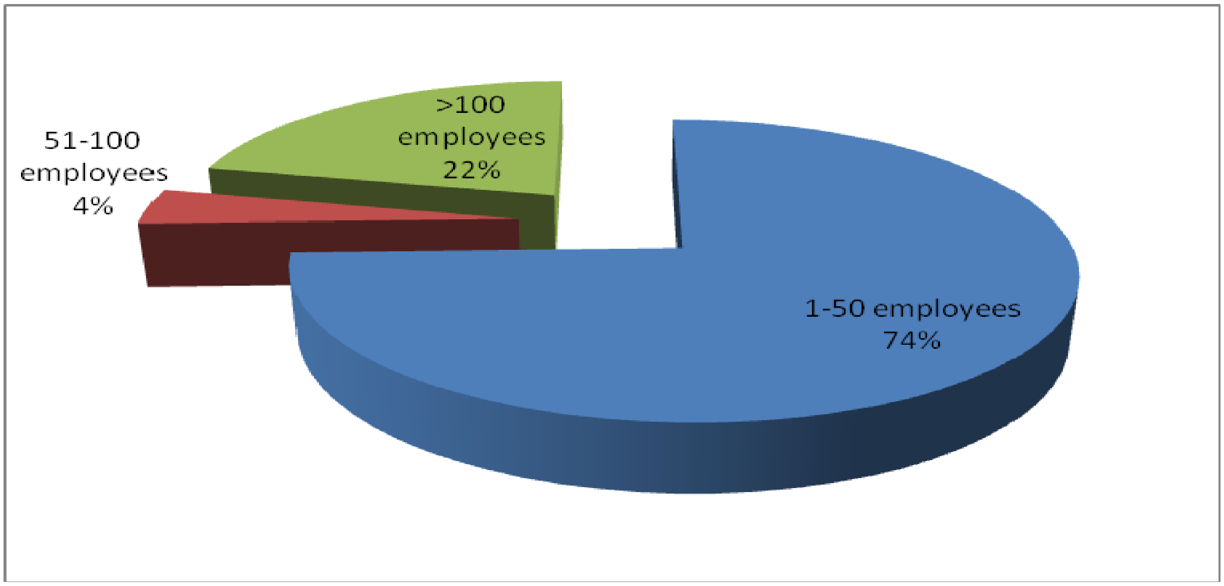

Figure 27: Percentage of workers based on the size of the mine involved in power haulage fatalities.

4.6 Machinery Fatalities Breakdown

Figure 28 shows that workers between the age of 45-54 had the highest percentage of total number of fatalities involving machinery (39%). Workers between the age of 17 and 24 had the lowest percentage of fatalities caused by machinery accidents (2%).

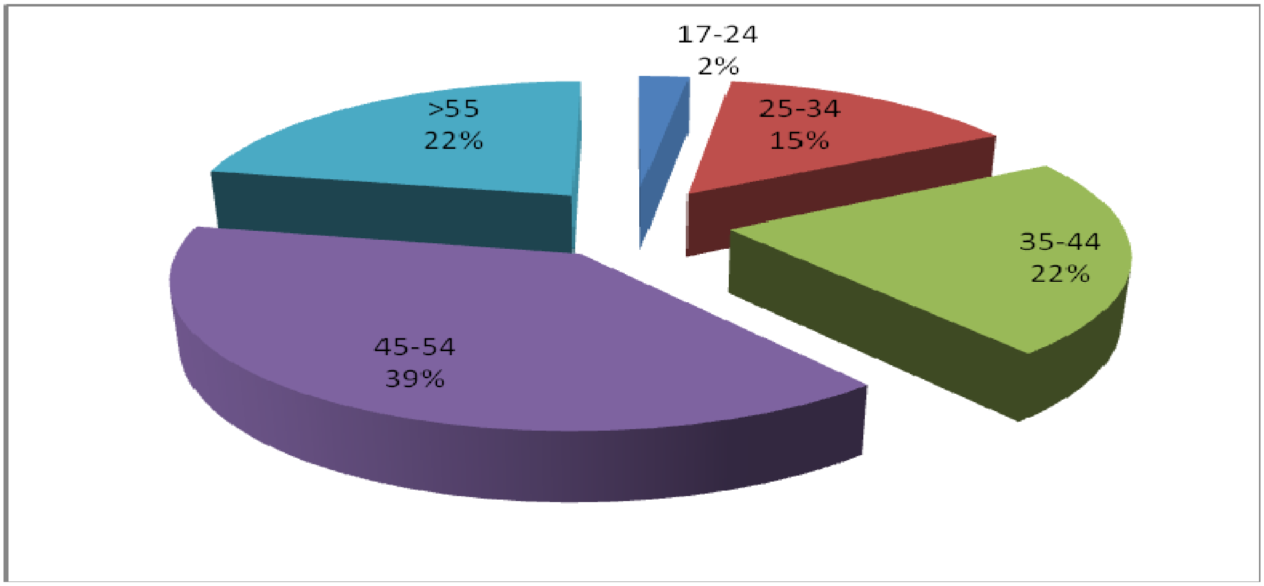

Figure 28: Percentage of workers based on age groups involved in machinery fatalities.

Figure 29 shows that workers with less than 5 years of experience represented more than half of fatalities caused by the machinery accidents (53%).

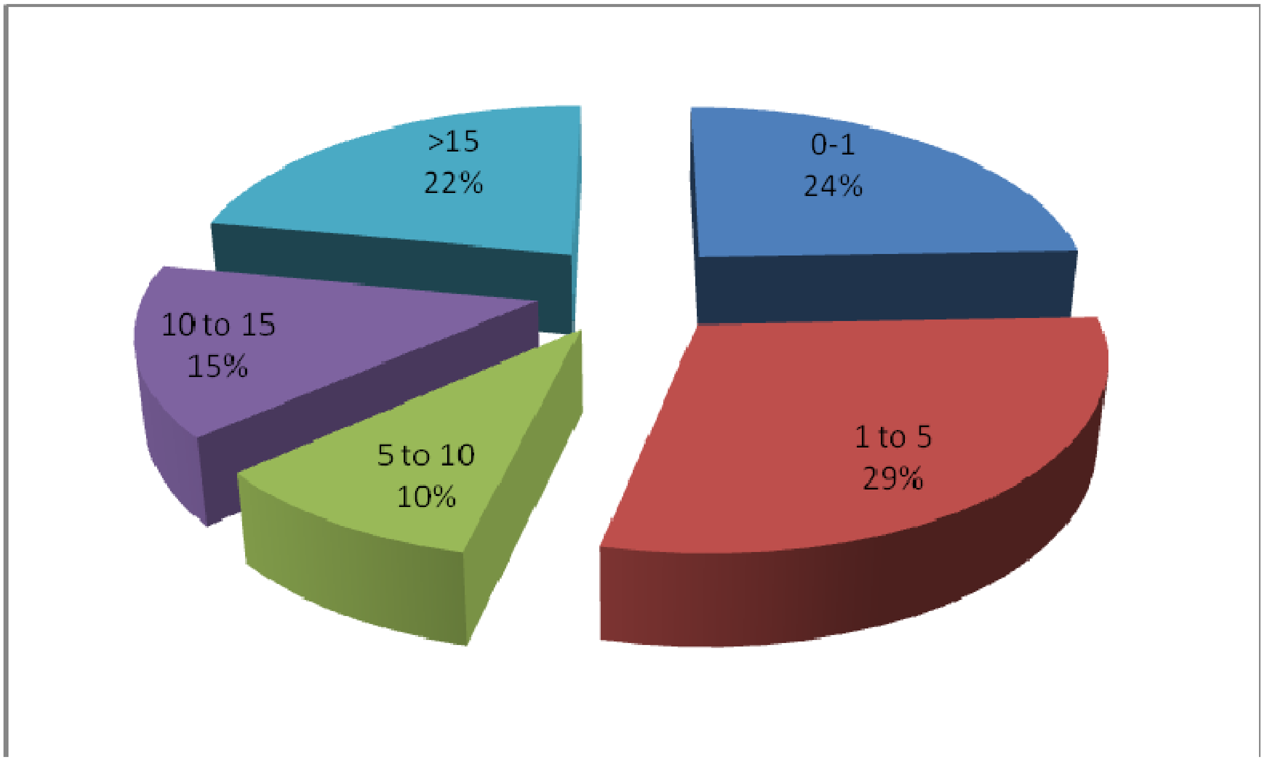

Figure 29: Percentage of workers based on years of experience involved in machinery fatalities.

Figure 30 shows that almost 71% the fatalities involving machinery occurred in mines with 1-50 employees. 29% of the fatalities involving machinery took place in mines with more than 100 employees while there was no fatality recorded for mines with employees between 51-100 employees.

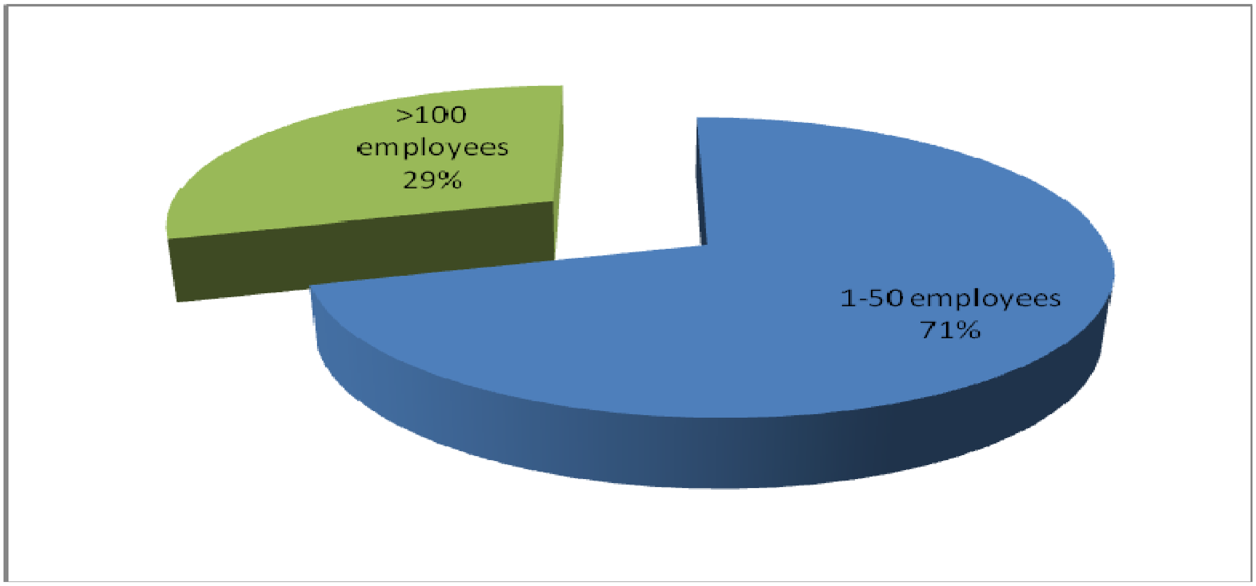

Figure 30: Percentage of workers based on the size of the mine involved in machinery fatalities.

4.7 Falling Material Fatalities Breakdown

Figure 31 shows the percentage of workers based on age groups whose injuries were categorized as falling material fatalities. The percentage of fatalities are almost similar in the age groups of 25-34, 35-44 and over 55 (22%) and 17% for age groups of 17-24 and 45-54.

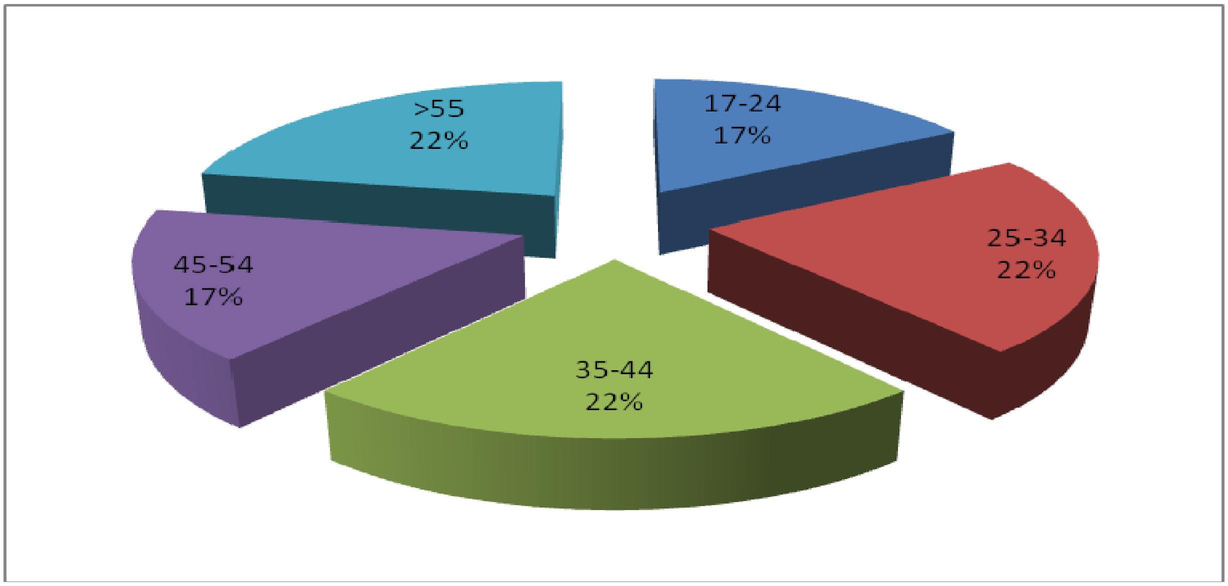

Figure 31: Percentage of workers based on age groups involved in falling material fatalities.

Figure 32 shows the percentage of workers based on years of experience involved in falling material fatalities. Workers with experience between 1 to 10 years represented 61% of the total fatalities involving falling materials.

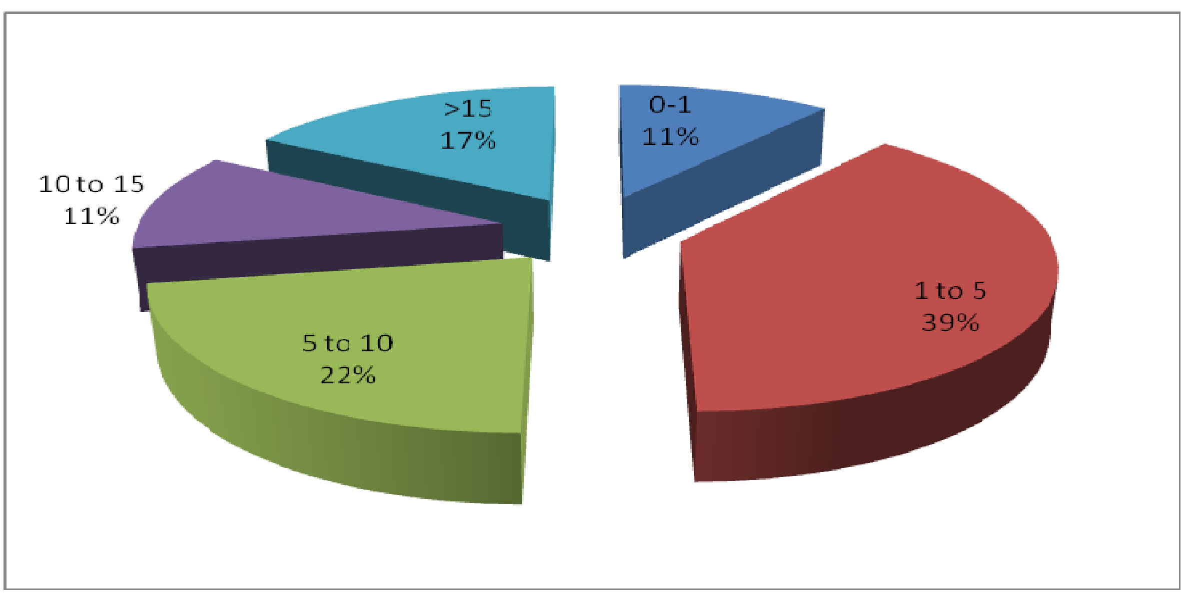

Figure 32: Percentage of workers based on years of experience whose injuries were categorized as falling material fatalities.

Figure 33 shows that almost 61% the fatalities involving falling material occurred in mines with 1-50 employees. 33% of the fatalities involving machinery took place in mines with more than 100 employees and 6% of fatality recorded for mines with employees between 51-100 employees.

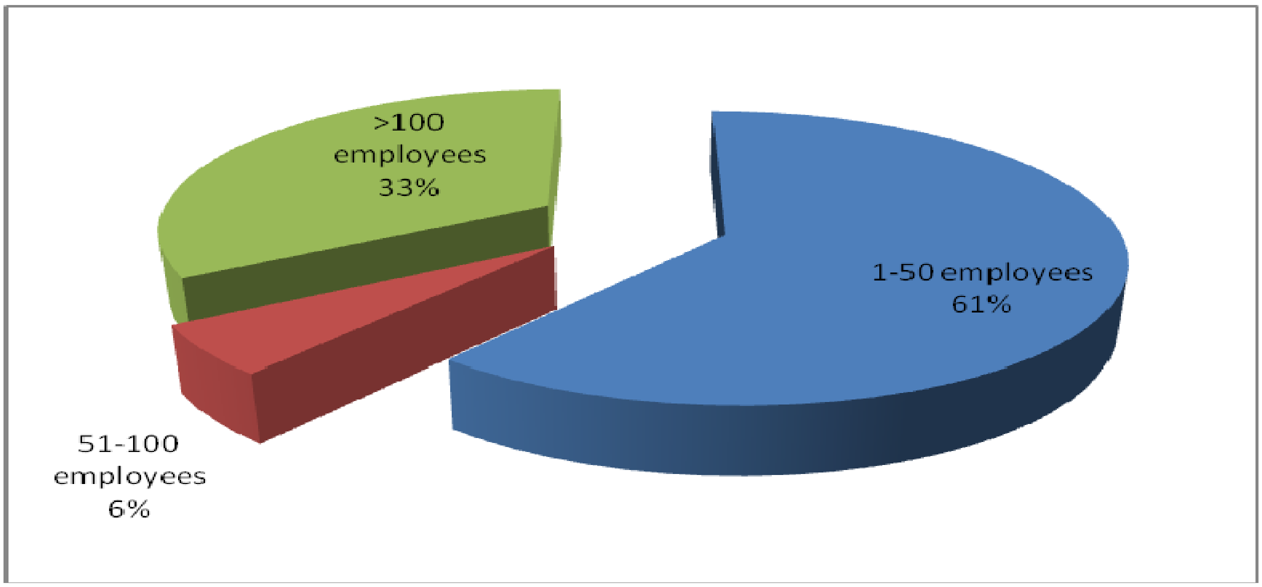

Figure 33: Percentage of workers based on the size of the mine involved in falling material fatalities.

4.8 Falling Person Fatalities Breakdown

Figure 34 shows the percentage of workers based on age groups whose injuries were categorized as falling person fatalities. Only 12% of these fatalities involved workers between the ages of 17 and 34 years old with workers between the ages of 35 and 44 years old representing almost half of the number of fatalities.

Figure 35 shows most of the workers involved in this fatality has less than 1 year of experience while Figure 36 shows that most of the fatalities came from large mines.

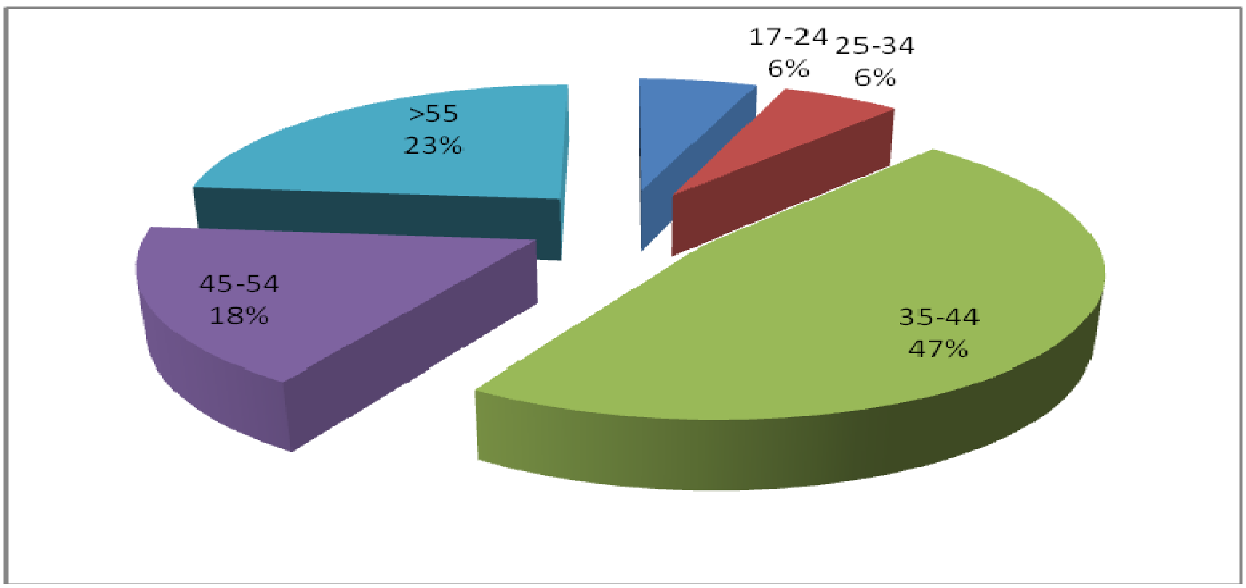

Figure 34: Percentage of workers based on age groups involved in falling person fatalities.

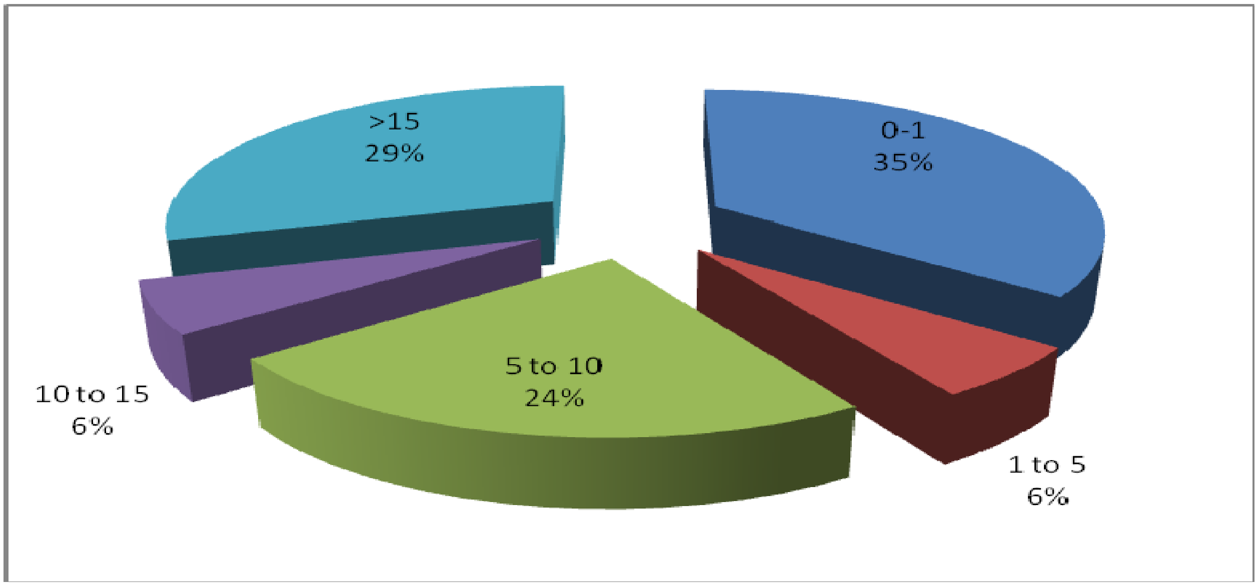

Figure 35: Percentage of workers based on years of experience involved in falling person fatalities.

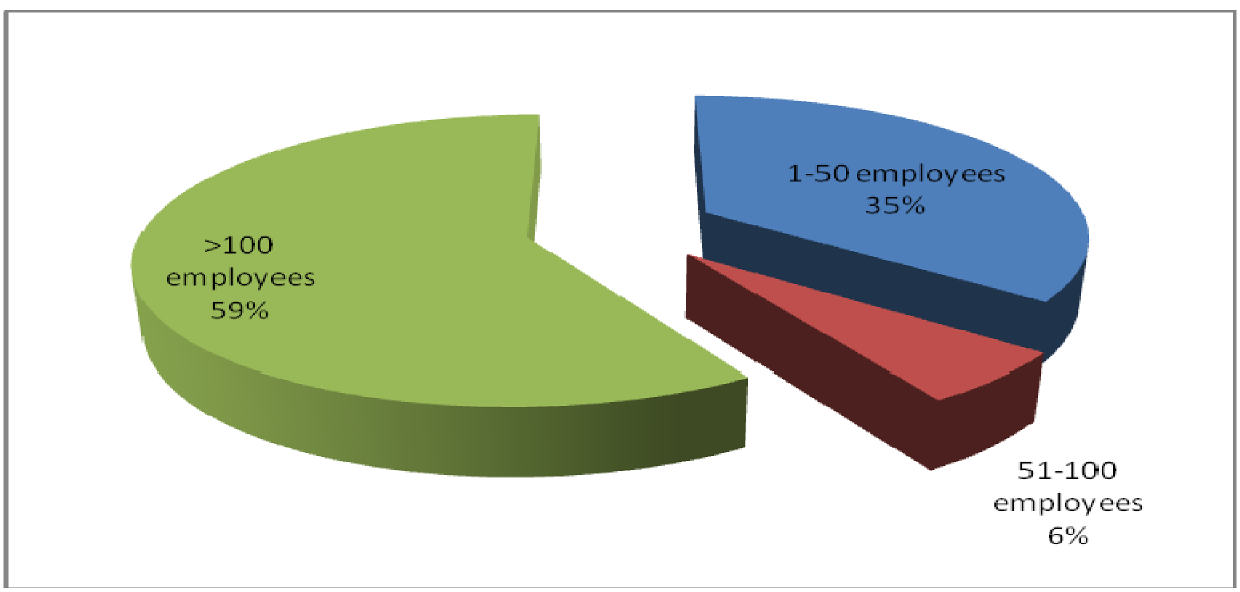

Figure 36: Percentage of workers based on the size of mines involved in falling person fatalities.

Chapter 5

Discussion

5.1 Implications

The results show the hypothesis -- older workers with less experience working in small mine is more likely to die in metal and non-metal mines is false. 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.

5.2 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. Based on this study, the prejudice that older workers have higher rates for fatality can be put at rest. Despite having high RI, younger workers between the ages of 17 and 24 years have the highest RI.

5.3 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.

5.4 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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Appendix A (Number of Fatalities)

Size	Age	Job Experience	2006	2005	2004	2003	2002	Total
1	1	1	3	3	1		1	**8**
1	1	2				2	3	**5**
1	1	3						**0**
1	1	4						**0**
1	1	5						**0**
1	2	1		1	1		1	**3**
1	2	2	1	5		1		**7**
1	2	3					1	**1**
1	2	4						**0**
1	2	5						**0**
1	3	1	2	2	1	2	2	**9**
1	3	2	1		1	3	3	**8**
1	3	3	1		2			**3**
1	3	4				1		**1**
1	3	5			3	1	1	**5**
1	4	1		3			3	**6**
1	4	2			1		3	**4**
1	4	3	2		1	2		**5**
1	4	4	1				2	**3**
1	4	5			1	5	2	**8**
1	5	1		1		2		**3**
1	5	2		2			1	**3**
1	5	3	3	1				**4**
1	5	4			1			**1**
1	5	5	4	2	3	1	3	**13**
2	1	1						**0**
2	1	2						**0**

2	1	3						**0**
2	1	4						**0**
2	1	5						**0**
2	2	1					1	**1**
2	2	2		1				**1**
2	2	3						**0**
2	2	4						**0**
2	2	5						**0**
2	3	1						**0**
2	3	2		1				**1**
2	3	3						**0**
2	3	4	1					**1**
2	3	5						**0**
2	4	1						**0**
2	4	2						**0**
2	4	3		1				**1**
2	4	4						**0**
2	4	5						**0**
2	5	1						**0**
2	5	2			1			**1**
2	5	3						**0**
2	5	4						**0**
2	5	5			1	1	1	**3**
3	1	1		1	1			**2**
3	1	2	1		1			**2**
3	1	3					1	**1**
3	1	4						**0**
3	1	5						**0**

3	2	1		2		1		**3**
3	2	2	1			1	3	**5**
3	2	3						**0**
3	2	4			2			**2**
3	2	5						**0**
3	3	1	1			1		**2**
3	3	2		1		2	1	**4**
3	3	3	1	1				**2**
3	3	4					1	**1**
3	3	5			1			**1**
3	4	1	1		2		2	**5**
3	4	2	1	1	1		3	**6**
3	4	3		1				**1**
3	4	4						**0**
3	4	5		3			1	**4**
3	5	1		1			1	**2**
3	5	2						**0**
3	5	3						**0**
3	5	4	1					**1**
3	5	5		1	1		1	**3**

Appendix B (Fatalities per 100,000 Workers)

	17-24	25-34	35-44	45-54	>55
Metal ore mining (in thousands)	2	6	10	13	3
Nonmetallic mineral mining and quarrying (in thousands)	4	13	27	22	13

Table B.1: Total number of workers in 2002 based on age

	17-24	25-34	35-44	45-54	>55
Metal ore mining(in thousands)	1	4	8	14	3
Nonmetallic mineral mining and quarrying(in thousands)	7	23	32	25	16

Table B.2: Total number of workers in 2003 based on age

	17-24	25-34	35-44	45-54	>55
Metal ore mining(in thousands)	1	2	6	5	3
Nonmetallic mineral mining and quarrying(in thousands)	6	20	34	35	14

Table B.3: Total number of workers in 2004 based on age

	17-24	25-34	35-44	45-54	>55
Metal ore mining(in thousands)	0	3	5	8	2
Nonmetallic mineral mining and quarrying(in thousands)	8	15	30	24	23

Table B.4: Total number of workers in 2005 based on age

	17-24	25-34	35-44	45-54	>55
Metal ore mining(in thousands)	2	7	8	14	4
Nonmetallic mineral mining and quarrying(in thousands)	7	23	25	27	24

Table B.5: Total number of workers in 2006 based on age

Year	17-24	25-34	35-44	45-54	>55
2002	6	19	37	35	16
2003	8	27	40	39	19
2004	7	22	40	40	17
2005	8	18	35	32	25
2006	9	30	33	41	28
Total	38	116	185	187	105

Table B.6: Total number of workers (in thousands) in metal and non-metal mines based on age

Year	17-24	25-34	35-44	45-54	>55
2002	5	6	8	16	7
2003	2	3	10	7	4
2004	3	3	8	6	7
2005	4	9	5	9	8
2006	4	2	7	5	8
Total	18	23	38	43	34

Table B.7: Fatalities in metal and non-metal mines based on age

Year	17-24	25-34	35-44	45-54	>55
2002	83.3333333	31.5789	21.6216	45.7143	43.75
2003	25	11.1111	25	17.9487	21.0526
2004	42.8571429	13.6364	20	15	41.1765
2005	50	50	14.2857	28.125	32
2006	44.4444444	6.66667	21.2121	12.1951	28.5714
Total	47.3684211	19.8276	20.5405	22.9947	32.381

Table B.8: Fatalities per 100,000 workers

Appendix C (Class of Accidents)

Class/Age Group	2002	17-24	25-34	35-44	45-54	>55
Falling Material	2	1	0	0	1	0
Machinery	13	1	1	3	6	2
Electrical	2	0	1	1	0	0
Powered Haulage	15	3	1	1	6	4
Fall of Highway	1	0	1	0	0	0
Fall of Person	2	0	1	1	0	0
Explosion	1	0	1	0	0	0
Hoisting	1	0	0	0	1	0
Other	5	0	0	2	2	1
Class/Age Group	2003	17-24	25-34	35-44	45-54	>55
Falling Material	3	0	1	1	1	0
Machinery	8	0	0	3	4	1
Electrical	2	0	0	0	2	0
Powered Haulage	6	2	0	2	0	2
Fall of Highway	0	0	0	0	0	0
Fall of Person	3	0	0	2	0	1
Explosion	1	0	1	0	0	0
Handtools	1	0	0	1	0	0
Other	2	0	1	1	0	0
Class/Age Group	2004	17-24	25-34	35-44	45-54	>55
Falling Material	4	1	2	0	0	1
Machinery	6	0	1	3	2	0
Electrical	1	0	0	1	0	0
Powered Haulage	7	1	0	3	1	2
Fall of Highway	1	0	0	0	1	0
Fall of Person	6	1	0	1	1	3
Explosion	1	0	0	0	1	0
Hoisting	0	0	0	0	0	0
Other	1	0	0	0	0	1
Class/Age Group	2005	17-24	25-34	35-44	45-54	>55
Falling Material	3	1	1	0	0	1
Machinery	10	0	3	0	3	4
Electrical	2	0	0	0	2	0
Powered Haulage	16	3	5	2	3	3
Fall of Highway	0	0	0	0	0	0
Fall of Person	3	0	0	2	1	0
Explosion	1	0	0	1	0	0
Hoisting	0	0	0	0	0	0

Other	0	0	0	0	0	0
Class/Age Group	2006	17-24	25-34	35-44	45-54	>55
Falling Material	6	0	0	3	1	2
Machinery	4	0	1	0	1	2
Electrical	5	1	1	0	1	2
Powered Haulage	7	1	2	1	1	2
Fall of Highway	1	0	0	1	0	0
Fall of Person	3	0	0	2	1	0
Explosion	0	0	0	0	0	0
Hoisting	0	0	0	0	0	0
Other	0	0	0	0	0	0
Total	156	16	25	38	43	34

Table C.1: Source of death and age group from 2002 to 2006

Class/Years of Experience	2002	<1	1-5	5-10	10-15	>15
Falling Material	2	0	0	1	0	1
Machinery	13	4	5	0	3	1
Electrical	2	1	1	0	0	0
Powered Haulage	15	3	7	0	1	4
Fall of Highway	1	1	0	0	0	0
Fall of Person	2	1	1	0	0	0
Explosion	1	0	1	0	0	0
Hoisting	1	1	0	0	0	0
Other	5	0	2	0	0	3
Class/Years of Experience	2003	<1	1-5	5-10	10-15	>15
Falling Material	3	0	2	0	0	1
Machinery	8	2	2	2	0	2
Electrical	2	0	0	0	0	2
Powered Haulage	6	2	3	0	1	0
Fall of Highway	0	0	0	0	0	0
Fall of Person	3	1	0	0	1	1
Explosion	1	1	0	0	0	0
Handtools	1	0	0	0	0	1
Other	2	0	2	0	0	0
Class/Years of Experience	2004	<1	1-5	5-10	10-15	>15
Falling Material	4	0	2	0	1	1
Machinery	6	0	2	0	2	2

Electrical	1	1	0	0	0	0
Powered Haulage	7	2	1	1	0	3
Fall of Highway	1	0	0	0	0	1
Fall of Person	6	1	0	1	0	4
Explosion	1	1	0	0	0	0
Hoisting	0	0	0	0	0	0
Other	1	0	1	0	0	0
Class/Years of Experience	2005	<1	1-5	5-10	10-15	>15
Falling Material	3	1	1	1	0	0
Machinery	10	4	2	0	0	4
Electrical	2	1	0	0	0	1
Powered Haulage	16	7	7	1	0	1
Fall of Highway	0	0	0	0	0	0
Fall of Person	3	1	0	2	0	0
Explosion	1	0	1	0	0	0
Hoisting	0	0	0	0	0	0
Other	0	0	0	0	0	0
Class/Years of Experience	2006	<1	1-5	5-10	10-15	>15
Falling Material	6	1	2	2	1	0
Machinery	4	0	1	2	1	0
Electrical	5	0	2	0	1	2
Powered Haulage	7	3	0	1	0	3
Fall of Highway	1	1	0	0	0	0
Fall of Person	3	2	0	1	0	0
Explosion	0	0	0	0	0	0
Hoisting	0	0	0	0	0	0
Other	0	0	0	0	0	0
Total	156	43	48	15	12	38

Table C.2: Sources of death and years of job experience

Class/Size of Mine(Number of employees)	2002	1-50	51-100	>101
Falling Material	2	0	0	2
Machinery	13	9	0	4
Electrical	2	1	1	0
Powered Haulage	15	10	0	5
Fall of Highway	1	1	0	0
Fall of Person	2	1	0	1
Explosion	1	0	0	1
Hoisting	1	0	0	1

Other	5	3	1	1
Class	2003	1-50	51-100	>101
Falling Material	3	2	0	1
Machinery	8	8	0	0
Electrical	2	2	0	0
Powered Haulage	6	6	0	0
Fall of Highway	0	0	0	0
Fall of Person	3	1	1	1
Explosion	1	0	0	1
Handtools	1	1	0	0
Other	2	0	0	2
Class/Size of Mine(Number of employees)	2004	1-50	51-100	>101
Falling Material	4	2	0	2
Machinery	6	4	0	2
Electrical	1	1	0	0
Powered Haulage	7	5	0	2
Fall of Highway	1	1	0	0
Fall of Person	6	3	0	3
Explosion	1	0	0	1
Hoisting	0	0	0	0
Other	1	0	1	0
Class/Size of Mine(Number of employees)	2005	1-50	51-100	>101
Falling Material	3	3	0	0
Machinery	10	5	0	5
Electrical	2	1	0	1
Powered Haulage	16	10	2	4
Fall of Highway	0	0	0	0
Fall of Person	3	1	0	2
Explosion	1	0	1	0
Hoisting	0	0	0	0
Other	0	0	0	0
Class/Size of Mine(Number of employees)	2006	1-50	51-100	>101
Falling Material	6	4	1	1
Machinery	4	3	0	1
Electrical	5	3	0	2
Powered Haulage	7	7	0	0
Fall of Highway	1	1	0	0

Fall of Person	3	0	0	3
Explosion	0	0	0	0
Hoisting	0	0	0	0
Other	0	0	0	0
Total	156	99	8	49

Table C.3: Sources of death and number of employees in the mine