CHAPTER 3

POTENTIAL ENVIRONMENTAL ERGONOMIC RISK FACTORS

3.1 INTRODUCTION

Several researchers have reported elevated rates of low back injury amongst vehicle drivers when compared to workers who do not drive as part of their job (Eger et al 2006a; Village et al 1989). Various environmental factors, including whole body vibration, combine to overload the vertebral column and its supportive structures during driving. Frequencies between 1 and 20Hz can cause the body, including spinal column, pelvis, internal organs and soft tissues to resonate (Kitazaki & Griffin 1998; Thalheimer 1996). The negative outcome include: lower back pain, spinal degeneration, gastrointestinal track problems, sleeping problems, headaches, neck problems and automatic nervous system dysfunction (Scutter et al 1997; Seidel, 1993, 2005; Thalheimer 1996). It is imperative that information be gathered to assist in designing better working conditions for vehicle drivers, which will enhance their health and well being, productivity morale and efficiency in performing their jobs. Hence, there is a current need to do research focusing on potential environmental ergonomic risk factors that might contribute to the knowledge of the development of lower back disorders among the vehicle drivers.
3.2 CONCEPTUAL FRAMEWORK

Studies have shown that lower back disorders are more prevalent in the operators of vehicles compared to the general population (Bongers & Boushuizen 1990; Bovenzi & Hulshof 1998). The cause of back pain is multifactorial in nature. (Kittuswamy & Buchholz 2004). Low back pain (LBP) is a common and costly problem making prevention an attractive model of approach for its containment. (Lings & leboeuf-Yde 2000). Therefore, a conceptual framework linking the relationship of potential risk factors, lower back disorder, prevention of activities and consulting doctor was established. Figure 3.1 shows the conceptual framework.

Figure 3.1 Conceptual framework

3.2.1 Variable Conceptualization

An attempt has been made to conceptualize the five potential risk factors contributing LBP (Constructs) as well as discomfort outcome (Low back pain prevalence level) and consequence (Prevention of activities and Medical intervention) based on various dimensions emphasized upon by different authors. And a lucid elucidation of each risk factor is provided.
3.3 POTENTIAL ENVIRONMENTAL ERGONOMIC RISK FACTORS

The potential environmental ergonomic risk factors considered in the study are given in the Table. 3.1.

Table 3.1 Potential Environmental Ergonomic Risk Factors.

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<td>Discomfort</td>
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3.3.1 Intensity of Whole Body Vibration
WBV is an oscillation with frequency ranging from 0.01 to 50Hz which is transmitted to the body that can cause motion sickness, discomfort, pain, vomiting, and paresthesia (numbness to the skin) (Uchikune 2004). Vibration exposure to the human body is complex, since the human body is exposed to various frequencies in different directions (Griffin 1990b).

The resonance of the human spinal system occurs most often within the band 4.5-5.5Hz. When vibration occurs at a frequency which is equal to the natural frequency (the unforced vibration of the body), a resonance (vibration occurring at maximum magnitude) occurs, which leads to large internal stresses and strain (Wilder & Pope 1996).

The extent of the oscillation determines the intensity of the vibration (Rehn 2004). In a review by National Institute for Occupational Safety and Health (NIOSH), the conclusion was that there was strong evidence for a positive association between exposure to WBV and back disorders. In a review of studies published from 1986 – 1997 by Bovenzi & Hulsholf (1999) concluded that occupational exposure to WBV was associated with an increased risk of low back pain, sciatic pain, and degenerative changes in the spinal system. Whole body vibration exposure of the train drivers working for State Railway Lines in Turkey was assessed by Birlik (2009) by referring to ISO standard 2631 -1 and EU directive 2002/44/EC. Daily exposure action values suggested in EU directive were exceeded in intercity train drivers and their exposure falls within the health caution zone of ISO 2631-1. It was concluded that they were under risk of having spinal disorders.
3.3.2 Posture

Posture is the position of the body, body segment(s) or joint(s) (Rehn 2004). Neutral posture is defined as the back being upright (ie head, shoulder and tail bone in a straight line). Posture shifts consist of deviations from neutral and were classified according to the direction (move forward, move back, move side, move up and other) and body part (neck, back etc).

Working posture is believed to be influenced by many factors including workstation lay out, location and orientation of work, individual working methods and the workers anthropometric characteristics (Hsiao & Keyserling 1990; Keyserling et al 1988). Awkward postures refer to joint positions significantly deviated from the neutral body postures and may include static positioning or constrained body postures (twisting or elevated positioning ; Putz -Anderson 1988). Exposure to awkward posture can result in localized fatigue or pain and contribute to the development of musculoskeletal disorders of spinal system.

Froom et al (1984) assessed the effect of the sitting positions of a helicopter crew (gunner and pilot) on the prevalence of LBP during flight and found that a vertical sitting position was adopted by the gunner, where as the pilot was leaning forward and to the left in order to operate the controls. The pilot positions associated with an increased prevalence of pain as well as earlier onset and increased intensity of pain.

Driving posture and whole body vibration were measured by Eger (2008) during the operation of seven load-haul-dump (LHD) mining vehicles and concluded that the simultaneous exposure to WBV and non-neutral working postures appear to increase musculoskeletal injury risk amongst LHD operators.
The important role of driver’s posture leading to musculoskeletal problems has been emphasized in the ergonomic review (Pope et al 2002a). Johanning (2006) has reported the important role of seating posture, awkward positioning and seat/cab adjustment features in the overall vibration exposure risk assessment in US locomotives. Mean basic vibration levels measured in the US locomotives appeared to be lower, in comparison with some road and off-road vehicles with a known high risk for lower back disorders and other problems (Hulshof & Zanten 1987; Bovenzi & Hulshof 1999).

A cross-sectional study was conducted by Okunribido et al (2007) among eighty bus drivers in Scotland using validated questionnaire, in which the questions regarding posture were in terms of five different possible configurations of the torso (torso against backrest, torso straight, torso bent, torso twisted and torso bent and twisted simultaneously) and three possible frequencies of occurrence (never, occasionally and often). The results indicated that five drivers (8.2%) adopted the ‘torso bent’ posture often during driving and thirty-five (57.4%) indicated the ‘torso against backrest’ posture. Only eight drivers (13.1%) and one driver respectively indicated that the ‘torso twisted’ posture and the ‘torso bent and twisted simultaneously’ posture were often adopted. Transient and mild LBP (not likely to interfere with work or customary levels of activity) was prevalent among city bus drivers.

3.3.3 Work environment (Road condition, Seat condition, Discomfort)

The work environment can be defined as the environment in which people work. It includes the physical setting (e.g. Vehicle characteristics, Road Condition), characteristics of the job itself (e.g. workload, task complexity). Research has shown WBV is affected by a number of variables including vehicle operating speed (Ozkaya et al 1994; Village et al 1989), vehicle
maintenance (Bovenzi 1996; Nishiyama et al 1998; Ozkaya et al 1994), vehicle size (Village et al 1989; Eger et al 2006a), vehicle suspension (Cann et al 2004a), seat suspension (Boileau et al 2006; Bovenzi 1996; Reid-Bush & Hubbard 2000), and road maintenance (Cann et al 2004a; Maeda & Morioka 1998; Malchaire et al 1996). In order to minimize WBV, driving speeds should be reduced, vehicles should be maintained, heavier vehicles should be utilized, roads should be maintained and vehicle and seat suspension should be suited to the work environment such that vibration is attenuated and not amplified (Eger et al 2008).

3.3.3.1 Road condition

Road condition refers to the pavement condition in relation to the vehicle as it drives over it. It is the current ability of a pavement to serve the traffic, it is meant to serve. The drivers were asked to indicate possible conditions of comfort and ride quality from very bad to very good in various categories of road. The classification of roads in India are expressways, national highways (NH), state highways (SH), major district roads (MDR), other district roads (ODR) and village roads (VR). Research has shown WBV gis affected by a number of variables including road maintenance (Cann et al 2004b; Maida & Morioka 1998; Malchaire et al 1996). In order to minimize the WBV, roads should be maintained.

3.3.3.2 Seat condition

Inclination of the seat and its height from the ground level, position and shape of the backrest and presence of armrests all contribute to influence the seated posture adopted. Considering that all postures become uncomfortable if maintained for long periods at a time, the seat should permit regular alterations of position.
Johanning et al (2006) found that existing cab and seat design in US rail road locomotives can result in prolonged forced awkward spinal posture of the operator combined with WBV exposure.

Helicopter operators, with relatively low and similar vibration levels described in the rail bound vehicles (locomotives), were also found to have a high rate of back disorders, possibly due to combined effects of vibration and forced awkward spinal posture (asymmetric) because of seat and cab design features. (Hulshof & Zanten 1987; Lopez & Lopez et al 2001; Colak et al 1992; Froom et al 1984).

**Seat suspension**

Several researchers have studied the benefits of providing the proper seat suspension that suit the work environment such that vibration is attenuated (Boileau et al 2006; Bovenzi 1996; Reid-Bush & Hubbard 2000).

Suspension of the seat itself (if any) constitutes the final stage of suspension before the operator. The majority of suspension seats are designed to ensure isolation only in vertical axis. Types of suspensions normally provided are non compact mechanical suspension, pneumatic suspension (Donati 2002).

**Non-compact mechanical suspension:**

These suspensions have a travel, which exceeds 4-5 cm. Seat cushion and back rest vertical motion is obtained by a mechanism located behind the backrest or beneath the seat cushion. Figure 3.2 shows the seat with mechanical suspension (Donati 2002).
Figure 3.2 Seat with mechanical suspension

Pneumatic suspension

In a pneumatic suspension system, the spring is replaced by an air pressure chamber which traps a volume of air. This suspension is easier to use and therefore more effective than a mechanical system because it allows automatic weight adjustment after actuating a control or by simply sitting on the seat. It requires a source of compressed air, which is supplied by a vehicle battery powered compressor located inside the seat. In general, greater efficiency is noted with pneumatic suspension seats. Figure 3.3 shows the seat with air suspension (Donati 2002).

Figure 3.3 Seat with air suspension
Type of seat suspension chosen should be such that when it is mounted on vehicles whose dominant motion frequencies are higher than the seat attenuation frequency. Seat suspension cut off frequency and suspension travel should be known. When a vibration frequency is less than the cut off frequency, the seat suspension effectively amplifies the vibration. A suspension seat must therefore be chosen such that its highest cut-off frequency (calculated for weight of the lightest driver) is lower than the cab floor vibration dominant frequency. Suspension travel must be sufficient to prevent bottoming or topping against end stops. In general, mechanical suspension seats will only isolate vibration at frequencies higher than 2Hz (Donati 2002).

Ergonomic and seating conditions are important and possible modifying factors in an overall risk assessment of WBV exposure (FRA 1996; John 1998) and for musculoskeletal health in occupational medicine (Johanning 2000).

3.3.3.3 Discomfort

Discomfort from whole body vibration can occur in any direction, i.e., vertically, side-to-side (laterally), or in fore-and-aft directions. It can even occur in more than one direction simultaneously. For whole-body vibration, the fore-and-aft direction is defined as the x-axis, lateral as the y-axis, and vertical as the z-axis. For a sitting person, the axes are those for the thighs (i.e., while standing, the feet is aligned to the x-axis). The basic centric axes on the human body is shown in Figure.3.4.
A study by Bovenzi & Betta (1994) among operators of agricultural tractors was one of the first to suggest that duration of exposure was more highly correlated with low back pain than the vibration magnitude alone, suggesting a possible close relationship. The investigators identified a significant increase in the likelihood of low back symptoms with an increase in total tractor driving hours. Exposure to WBV at least half the working time was associated with prevalence ratios above two for musculoskeletal symptoms among Swedish workers (Hagberg et al 2006).

In a logistic regression analysis performed by Johanning et al (2006) from the data collected among US locomotive operators, the variable ‘time at work being bothered by vibration’ (h/day) was strongly associated with an increased risk of low back pain, shoulder and neck pain and sciatic pain. Each hour being bothered by vibration increased risk of pain approximately 20%. Each 10 years of Railroad employment was associated
with an additional 38% risk for back disorders at the measured vibration levels.

Exposure to WBV at least half the working time was associated with prevalence ratios above two for musculoskeletal symptoms in the low back, neck shoulder/arm and hand among Swedish work force was concluded from the survey conducted by Hagberg et al(2006).

However, these studies do not provide sufficient ground work on Break duration for prevalence of low back pain in vehicle drivers. Since duration of break between the driving hours and break duration activities could useful in minimizing the risk of lower back disorders among drivers. Research on Break duration factors could contribute significantly in reducing the LBD prevalence. Towards this endeavour, this research work investigates empirically the relationship between levels of Break Duration and LBD prevalence.

### 3.3.5 Psychosocial Factors (Psychosocial Work Aspect and Psychosocial Personal Aspect)

The expression ‘psychosocial factors’ is a nonspecific term. In its general usage in occupational health, the term has served as catch-all in reference to nonphysical elements of the job/work environment, including organizational climate or culture, aspects of work organization such as the complexity of tasks, and even psychological attributes of worker such as job attitudes (e.g. job satisfaction) and personality traits (Sauter & Swanson 1993).

The psychosocial work environment constitutes an important part of an ergonomics evaluation of a workplace. Psychosocial work factors are defined as aspects of the work environment (such as work roles, work
pressure, relationships at work) that can contribute to the experience of stress in individuals (Lim & Carayon 1994; ILO 1986).

Job satisfaction is a contribution of psychological, physiological and environmental factors that makes a person to admit, “I am happy at my job” (Hoppock 1935). Bullock (1952) viewed job satisfaction as an attitude, which results from a balancing and summation of many specific likes and dislikes, experienced in connection with the job.

Increasing evidence suggests that exposure to adverse work organization characteristics, such as high performance demands, coupled with low levels of job control and low workplace social support, places individuals at increased risk of stress and illness (Karasek & Theorell 1990).

The National Institute for Occupational Safety and Health (NIOSH 1997) outlines five psychosocial factors that are related to back and upper extremity disorders as job satisfaction, intensified workload, monotonous work, job control and social support.

A psychosocial factor may be defined as a measurement that potentially relates psychosocial phenomena to the social environment and to pathophysiological changes. For LBP, it has been hypothesized that exposure to suboptimal psychosocial factors may lead to altered spinal loading due to increased muscle tension. This then possibly affects the nutrition of intervertebral discs, nerve roots, and other spinal tissues (Bonger et al 1993; Bergenudd & Johnell 1991). Further, raised plasma cortisol levels following high psychological demands may leave muscles vulnerable to mechanical loads. The consequences and prognosis of LBP could also be influenced by psychosocial factors. Clearly, one must differentiate between pain and disability. Pain originates from injured tissues where as psychosocial factors, such as work satisfaction, can have an influence on disability (Magnusson et al 1993).
For example, pain that under optimal circumstances would be tolerated by workers may in a stressful psychosocial environment lead to injury reporting due to decreased pain tolerance (Burton & Erg 1997). Further, as suggested by Nachemosson (1992), workers may be more inclined to take sick leave in poor psychosocial environments.

Psychosocial factors have been consistently found to be associated with LBP, with disability arising from LBP, and with treatment outcome. (Bigos et al 1991). Poor psychosocial work environment and work dissatisfaction have also been found to be associated with LBP and development of chronicity (Williams et al 1998) although contradictory findings have been reported (Skovron et al 1987).

In a prospective cohort study of risk factors for musculoskeletal symptoms with the study population of 861 workers in Netherlands, Hoogendoorn et al (2001) concluded that there was a 1.3 to 1.6 fold increased risk of low back pain for workers with high quantitative job demands, for workers with high conflicting demands, for workers with low supervisory support and for workers with low co-worker support.

3.4 CONCLUSION

Nine potential environmental ergonomic risk factors relating to LBD prevalence have been identified through an extensive literature survey. All these nine variables have been discussed fully in this chapter. Based on this information, operating elements for each variable, designed for the purpose of constructing the measuring instrument. Design of questionnaire, testing and validation of the same, are discussed in the next chapter.