MODELING OF WORK-RELATED MUSCULOSKELETAL DISORDERS IN CHEMICAL PROCESS INDUSTRY IN INDIA

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By

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Ph.D. Thesis

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Dedicated to……

My Parents

Sri. C P Janardhanan

&

Smt. M R Sulochana

Certificate

This is to certify that the thesis entitled "MODELING OF WORK - RELATED MUSCULOSKELETAL DISORDERS IN CHEMICAL PROCESS INDUSTRY IN INDIA" is an authentic original work done by PRAVEENSAL C.J. under my supervision and guidance in School of Engineering, Cochin University of Science and Technology. No part of this thesis has been presented for any other degree from any other institution.

Prof. G.MADHU
Supervising Guide

DECLARATION

I hereby declare that the work presented in the thesis entitled "MODELING OF WORK-RELATED MUSCULOSKELETAL DISORDERS IN CHEMICAL PROCESS INDUSTRY IN INDIA" is based on the original work done by me under the supervision of Prof. G.MADHU, Division of Safety and Fire Engineering, School of Engineering, Cochin University of Science and Technology. No part of this thesis has been presented for any other degree from any other institution.

Kochi-22 *PRAVEENSAL C.J.*

28th February 2013

The endless thanks go to God for all the blessings showered onto me, which has enabled me to write this last note in my research work. During the period of my research, as in the rest of my life, I have been blessed by Almighty with some people who have spun a web of support around me. Words can never be enough in expressing how grateful I am to those incredible people in my life that made this thesis possible. I would like an attempt to thank them for making my time during my research a period I will treasure.

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I take this opportunity to dedicate this work to my parents who have made me what I am, my wife Sreeji and my kids Saketh and Tarun who have given consistent support throughout my research.

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ABSTRACT

In this modern complex world, stress at work is found to be increasingly a common feature in day to day life. For the same reason, job stress is one of the active areas in occupational health and safety research for over last four decades and is continuing to attract researchers in academia and industry. Job stress in process industries is of concern due to its influence on process safety, and worker‘s safety and health. Safety in process (chemical and nuclear material) industry is of paramount importance, especially in a thickly populated country like India. Stress at job is the main vector in inducing work related musculoskeletal disorders which in turn can affect the worker health and safety in process industries. In view of the above, the process industries should try to minimize the job stress in workers to ensure a safe and healthy working climate for the industry and the worker. This research is mainly aimed at assessing the influence of job stress in inducing work related musculoskeletal disorders in chemical process industries in India.

Initially a multivariate statistical analysis was carried out utilizing exploratory and confirmatory factor analysis with the help of a questionnaire survey conducted in chemical process industries in the state of Kerala, India. The purpose of this study is to bring to light the determinants of job stress and to propose a comprehensive model and an instrument framework for measuring job stress in chemical process industries. The analysis revealed four factors that influence the job stress in chemical process industries. The analysis showed that the physical work factors to be the most and working environment to be the least influential factors in inducing the job stress in process industries in the country.

Based on the outcomes of confirmatory factor analysis and the insights from the job stress literature, a detailed feedback loop study was carried out for the influence of job stress in inducing work related musculoskeletal disorders in chemical process industries in India. The causal relationships developed in the feedback loop model were based on the available knowledge about the real system, outcomes of the confirmatory factor modeling efforts and the insights from the literature reviewed. The developed feedback loop model captures the dynamic interactions between variables in the system considered which include the job stress, its factors of role ambiguity, role conflict, physical work factors, work environment, absenteeism and job involvement. All these causal mechanisms are combined into a system dynamics model. The two policies of improved physical work factors and work environment are clubbed and experimented towards the mitigation of job stress induced work related musculoskeletal disorders in chemical process industries in India. It has been found that this combined policy performs the best towards mitigating the work related musculoskeletal disorders in chemical process industries in the country.

Keywords: *Job stress, Chemical process industry, Exploratory factor analysis, Confirmatory factor analysis,System dynamics modeling, Policy experimentation.*

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List of Abbreviations

AB	Absenteeism
AGFI	Adjusted Goodness of Fit Index
AR	Additional Responsibilities
B	Balancing
BLS	*Bureau of Labour Statistics*
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CLD	Causal Loop Diagram
CTD	Cumulative Trauma Disorder
CTS	Carpel Tunnel Syndrome
DL	Decision Latitude
EFA	Exploratory Factor Analysis
GFI	Goodness of Fit Index
IFI	Incremental Fit Index
ILO	*International Labour Organization*
JA	Job induced Anxiety
JI	Involvement in Job
JS	Job Stress
JSE	Job Security
JSLI	Job Stress Level Index
JST	Job Satisfaction
KMO	Kaiser Mayer Olkin
MLE	Maximum Likelihood Estimation
MSD	Musculoskeletal Disorder

NE	Neuroticism
NFI	Normed Fit Index
NIOSH	National *Institute for Occupational Safety and Health*
NRC	*National Research Council*
PWF	Physical Work Factors
Q	Question
R	Reinforcing
RA	Role Ambiguity
RC	Role Conflict
RFI	Relative Fit Index
RMI	Repetitive Motion Injuries
RMSEA	Root Mean Square Error of Approximation
RSI	Repetitive Strain Injuries
RU	Rumination
SD	System Dynamics
SEM	Structural Equation Modeling
SP	Supervisor's Performance
SPSS	Statistical Package for the Social Sciences
SS	Social Support
ST	Structure
TLI	Tucker Lewis Index
TPH	Threat of Physical Harm
WE	Working Environment
WHO	*World Health Organization*
WRMSD	Work -Related Musculoskeletal Disorders

Chapter 1

INTRODUCTION

Contents

1.1 Introduction

This research falls into the broad category of safety system modeling and management, and specifically into the assessment of job stress influence on work-related musculoskeletal disorders. The job stress in organisations is considered as an issue that needs to be addressed. The job stress is in turn a vector in inducing the musculoskeletal disorders in the work place. For the same reason the assessment of the effect of job stress on work-related musculoskeletal disorders is also important from a research point of view. The present research work considers the work-related musculoskeletal disorders - job stress system in the chemical process industries in India. Keeping this in mind, the objectives of the thesis have been framed, and a detailed methodology is laid out to attain these objectives. A brief overview of the chapters of the thesis is also presented.

1.2 The Theme

For most people work is the central part of their lives. It's the place where they spend most of their waking hours and most of their energy.

Moreover, how we judge ourselves and measure our self-worth is very much determined by the work we do. The status and rewards that society attaches to jobs is one of the primary ways others see us. Therefore, if work is unfulfilling in that it prevents workers from fully realizing their own potential and developing their human capacities, the nature of work becomes a primary stressor in our lives. Under these conditions, we experience an important aspect of our daily lives as an assault on our dignity as human beings.

When we feel inadequate, upset, insecure, or threatened, we often hesitate to talk about it, due to the belief that we are the only ones experiencing these problems. By doing this, we keep ourselves away from connecting with co-workers and thus end up feeling isolated, which induces stress. Learning to appreciate co-workers as allies is the first step in overcoming job stress. Moreover, it is only through the co-workers that workers can effectively develop and implement common strategies to challenge stressful working conditions.

Among the major negative effects of job stress are its impact on a person's self-image and self-esteem, which in turn, affects one's relationship with family, friends, and co-workers. The problems last far longer than the time we spend at work and are not easily left behind at the end of the day. So analysing working conditions as a primary source of stress is an important first step in overcoming it, especially because in many situations the long-term effects show up in our private lives and the workplace link can be lost altogether.

In 2008-2009, 1,958,000 people in the UK reported suffering from an illness that was caused or made worse by their current or past work. Of these, 52 percent reported musculoskeletal disorders (MSDs), and 21 percent reported stress, depression or anxiety. In terms of the 523,000 new cases of work-related illness reported in this period, these two types of disorder accounted for 73 percent of cases (37 percent for stress, depression or anxiety, and 36 percent for MSDs). Not only are stress and MSDs the two most common causes of work-related ill-health, but there is also growing interest in the links between the two conditions, both in terms of common risk factors and the extent to which the conditions themselves are mutually influential.

Due to the common risk factors associated with the onset of both MSDs and stress – depression or anxiety – it is perhaps unsurprising that an association has also been identified between the conditions themselves. For instance, high perceived job stress has been consistently associated with upper extremity problems. Most of this type of research, however, has been cross-sectional in nature (within a narrow time span), making it difficult to determine causation. The small number of prospective epidemiological studies that does exist provides support for a predictive relationship between symptoms of stress and MSDs. Therefore, this study focuses on exploring the influence of job stress on musculoskeletal disorders in organisations in India. The organisation chosen for the present study are chemical process industries in the country.

1.3 Research Issues

This research is aimed at establishing the role of job stress on the development of work-related musculoskeletal disorders in chemical process industries in India. Thus taking into consideration the importance of studying the influence of job stress and its factors in inducing work-related musculoskeletal disorders in chemical process industries; this research endeavor identifies the following research issues:

1. What are the determinant factors that induce job stress in chemical process industries?
2. How does job stress, induced by these factors, influence work-related musculoskeletal disorders in chemical process industries?
3. What interventions can be adopted to mitigate this job stress induced work-related musculoskeletal disorders in chemical process industries in Kerala, India?

1.4 Objectives of the Thesis

In view of the research issues identified in the previous section, the following objectives are formulated for the thesis:

1) To identify the attributes of job stress leading to work-related musculoskeletal disorders and determination of the factors of importance from the literature reviewed.
2) To develop an instrument framework for measuring workplace job stress based on identified factors with focus on chemical process industries in the state of Kerala, India.

3) To develop a dynamic model for analyzing the influence of job stress and its factors on work-related musculoskeletal disorders in chemical process industries.

4) To formulate policies to mitigate the work-related musculoskeletal disorders out of job stress in chemical process industries in the state of Kerala, India.

1.5 Scope of Work

The scope of the present research is as follows:

1) The research work was carried out in the chemical process industries in Kerala state, India.

2) The study is based on a questionnaire survey carried out in selected chemical process industries in Kerala, India.

1.6 The Research Framework

In order to study the influence of job stress and its variables on work-related musculoskeletal disorders in chemical process industries in India, the methodological sequence followed in this thesis is enumerated below.

Based on an elaborate literature review, field visits to chemical process industries and discussions with the experts in the same on the job stress and musculoskeletal disorders in workers, a questionnaire was prepared. The step following the questionnaire survey is the statistical analysis. The result of the multivariate statistical analysis is to serve as inputs to the feedback loop analysis. Based on the feedback loop analysis, a system dynamics simulation model was developed for quantifying the effects of job stress and its associated factors on work-related musculoskeletal disorders in chemical process industries in the country. The broad methodology adopted in the thesis for achieving the objectives is shown in Figure 1.1 in the form of a flow chart.

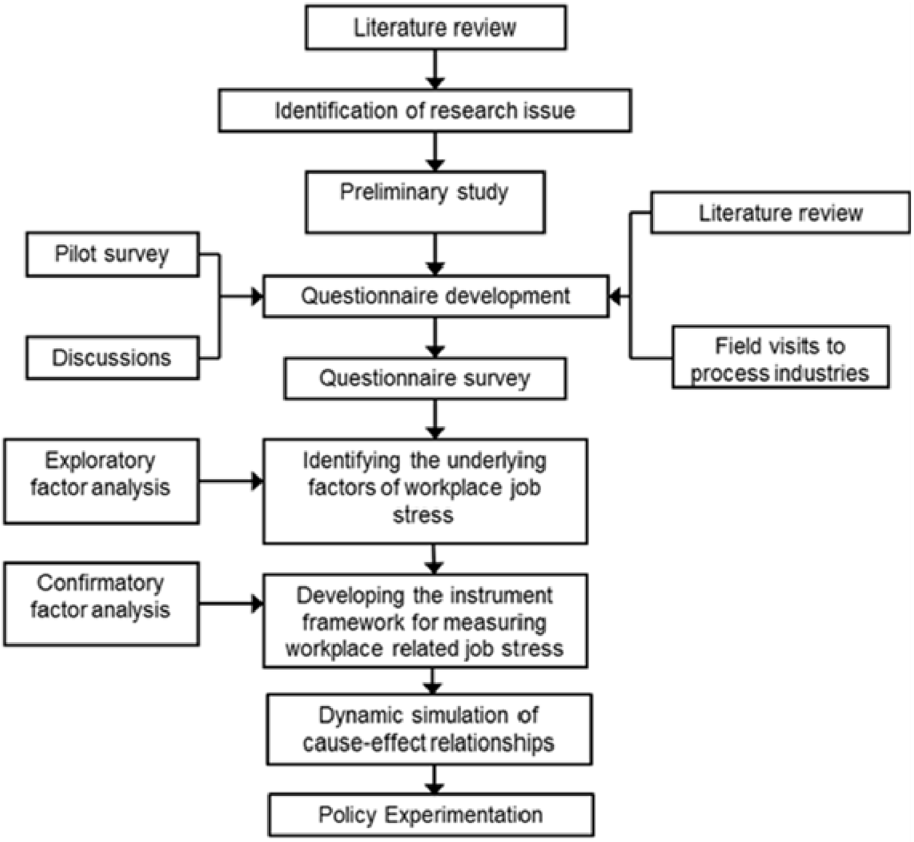

Figure 1.1: The Framework of Research Work

1.7 Organization of the Thesis

The thesis is organized in six chapters. The contents of each chapter are presented is presented in subsequent sections.

Chapter 1: Introduction

This chapter introduces the work, discusses the theme of the thesis and focuses on the importance and need for the study of job stress and its influence on work-related musculoskeletal disorders in chemical process industries in India. Specifying the background with which the current work is taken up, the chapter sets up the objective of this research work. Thereafter, it gives the methodology and scope of the work to accomplish the objectives. The chapter ends with a brief chapter-wise summary of work done in the thesis.

Chapter 2: Literature Review

This chapter provides an up-to-date review of literature in the areas related to the research in the thesis. The areas include job stress, studies relating to job stress in various sectors, factors determining job stress, studies on job stress and work-related musculoskeletal disorders, and policy experimentations. This chapter also gives a review of modeling tools and techniques with which the research work is carried out.

Chapter 3: Modeling and Development of an Instrument Framework for Measuring Job Stress in Chemical Process Industries in India

The purpose of this chapter is to bring to light the determinants of job stress and to propose a comprehensive model and an instrument framework for measuring job stress in chemical process industries in the state of Kerala, India. To accomplish this aim, the data was collected through a questionnaire survey which was conducted among 1197 employees in eight major chemical process industrial units in Kerala. The collected data was initially subjected to principal component factor analysis with varimax rotation to develop the job stress factor structure. Finally, the proposed instrument was tested for reliability and goodness-of-fit thereby confirming its structure using confirmatory factor analysis approach. The study identified eight factors that influence the job stress in chemical process industries and which are role ambiguity, role conflict, physical work factors, work environment, decision latitude, threat of physical harm, social support and additional responsibilities. The results of the present study also showed the factors of role ambiguity, role conflict, physical work factors and working environment to be the most influential factors in inducing the job stress in process industries in India. Finally, the study offers a job stress instrument that can be used to evaluate the level of job stress in process industries towards devising management activities for mitigating the same. Moreover, the instrument can be used as a benchmark tool for different process industries and even for departments in a process industry to compare the state of job stress prevailing.

Chapter 4: Effect of Job Stress in Inducing Work-Related Musculoskeletal Disorders in Chemical Process Industries in India – A Feedback Loop Study

In this chapter, a conceptual modeling framework is developed to capture the feedback loops appropriate for assessing the effective of job stress in inducing work-related musculoskeletal disorders in chemical process industries in India. These feedback loops are utilized to capture the interconnectedness amongst the variables in the work-related musculoskeletal disorder – job stress system in relation to the Indian chemical process industries under study. The causal relationships developed in the feedback loop model were based on the available knowledge about the real system, outcomes of the structural modeling efforts and the insights from the literature reviewed. The developed feedback loop model captures the dynamic interactions between variables in the system considered which include the job stress, its factors of role ambiguity, role conflict, physical work factors, work environment, absenteeism and job involvement.

Chapter 5: Dynamic Modeling for the Influence of Job Stress on Work-Related Musculoskeletal Disorders in Chemical Process Industries in India

In this chapter we quantify and analyze the effects of job stress and the influence of its factors of role ambiguity, role conflict, physical work factors and work environment on work-related musculoskeletal disorders and related absenteeism in chemical process industries in India using system dynamics tools. Based on the feedback loop study, a stock and flow diagram (Forrester, 1961) is developed to simulate the effects of job stress on musculoskeletal disorders in Indian chemical process industries.

Two policies of improved physical work factors and work environment are clubbed and experimented towards the mitigation of job stress induced work-related musculoskeletal disorders in chemical process industries in India. It has been found that this combined policy performs the best towards mitigating the work-related musculoskeletal disorders in chemical process industries in the country.

Chapter 6: Summary, Conclusions, and Future Scope of Work

This chapter gives the summary of the thesis followed by the conclusions of the research work undertaken and the contributions of the present research work. The chapter also discusses the scope for future work in the line of work-related musculoskeletal disorders and job stress modeling.

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Chapter 2

LITERATURE REVIEW

Contents

2.1 Introduction

This chapter provides a comprehensive review of literature related to the job stress and its influence on work-related musculoskeletal disorders research. Research on the job stress and musculoskeletal disorders in workers in various industries is carried out widely around the world. Even though the research on job stress and its relation to work-related musculoskeletal disorders is in plenty, this research in chemical process industries in India is sparse. Thus the intent of conducting this review is twofold. First, it is aimed to introduce thejob stress and work-related musculoskeletal disorders in organisations. Secondly, to understand the status of job stress and work-related musculoskeletal disorder research. To accomplish these aims, the review of literature is presented in the following two sections.

a) The literature on job stress and work-related musculoskeletal disorders;
b) The job stress and work-related musculoskeletal disorders research

The first section presents the literature on job stress and work-related musculoskeletal disorders in organisations. The second section is on the status of job stress and work-related musculoskeletal disorders research around the globe. The third section gives a review of modelling tools and techniques utilized in the work-related musculoskeletal disorder – job stress system research carried out in this thesis.

2.2 Literature on Job Stress and Work-Related Musculoskeletal Disorders

This section reviews the literature related to the job stress definition, job stress effects, job stress research around the globe, work-related musculoskeletal disorders, and the association of job stress and work-related musculoskeletal disorders.

2.2.1 Job Stress Defined

The term "stress" was first used by Selye (1936) in the literature on life sciences, describing stress as "the force, pressure, or strain exerted upon a material object or person which resist these forces and attempt to maintain its original state." Generally, stress is defined as the emotional and physiological reactions to stressors (Maslach et al., 1996; Zastrow, 1984); and one or more of these stressors can be induced by the work or job settings. Stress that happens due to a person's employment is termed job stress. Hence, job stress is defined as the harmful physical and emotional responses that occur when job requirements do not match the worker's capabilities, resources, and needs (NIOSH, 1999). It is recognized world-wide as a major challenge to individual mental and physical health, and organizational health (ILO, 1986). According to Kahn et al. (1964), stress can be viewed as individuals' reactions to the characteristics of work environment. According to Cooper et al (2001), the most wide spread definitions of job stress may be classified into three types. The first type of definition is stimulus based. It considers stress as an environmental based stimulus, forced upon the person. The second type of definition is response based. It defines stress as an individual's psychological or physiological response to the situational forces. The third definition of stress applies an interactive approach often called the stressor-strain approach. Moreover, Lazarus (1999) has defined stress as a state of worry that arises from an actual or apparent demand that calls for a change in behaviour. It is considered to be an internal state or reaction to anything we consciously or unconsciously perceive as a threat, either real or imagined (Clarke and Watson, 1991). Robbins (2001) defines stress as a dynamic condition in which the individual is confronted with an opportunity, constraint, or demand related to what the individual desires and for which the outcome is perceived to be both uncertain and important. Stress can also be defined as an adverse reaction that people experience when external demands exceed their internal capabilities (Waters &Ussery, 2007).

2.2.2 Job Stress and its Effects

In the past two decades, interest in the concept of stress and research on stress has reached an all-time high (Goldberger &Breznitz, 1993). Originally, stress was seen primarily as a physical ordeal to which humans take action. More lately, it has been linked to physical measures, as well as the assessment of actions, which is a cognitive occurrence (Jones et al., 2001). Stress generally has been familiar as a disagreeable emotional condition, which is said to occur when there have been extended, increasing or new forces that are significantly greater than the coping resources (Siegrist, 2001).

The penalties of stress include health harms and reduction in work success. It pressure negatively on the organization and the individual's physical and mental system. This could result in summary performance, absenteeism, accidents, unprincipled behaviour, displeasure and sickness. Continued high levels of stress can direct to serious health circumstances including hypertension cancer, and psychological illnesses such as sadness or collapse (Palmer et al., 2003). According to Kyriacou (1989), symptoms of stress in workers are manifested in frustration, damage performance, and split relationships at work and at home. Researchers agree that a certain extent of stress is a usual part of life, but prolonged stressors could lead to signs that are physical, psychological or behavioural (O'Driscoll and Beehr, 2000). The Indian Council for Research on International Economic Relations is projecting a possible twenty fold increase in lost productivity due to health issues over the next decade owing to increasing stress disorders amongst employees especially in the industrial sector. Those predominantly affected belong to the labour class as in other developing countries. Work-related stress and mental fatigue are mainly blamed on expectations of better performance, deadlines and competition over the last few years. The WHO reports 35 percent of cardiac disease related deaths in India by 2030 will be due to job stress. According to the WHO, 30 percent of suicidal deaths in India are due to job stress (WHO, 2007).

2.2.3 Job Stress Research around the Globe

In the past decade, effects of economic globalization and quick ethnical changes have resulted in increased workloads and a faster pace in the work place. Up to date trends such as organizational downsizing, struggle for funding, and high insist jobs have led to rising job stress (Dollard, 2003). The causes of job stress are many and different for each individual. In addition, the causes of stress are difficult to analyse. Many studies of stress at work have shown that there is a diversity of organizational factors that are active in causing stress (Sutherland and Cooper, 2000). Job stress may occur due to stress factors at the individual level, or at the organization level or at the interface of the two (Van der Hek and Plomp, 1997). Job stress is regarded to be influenced by factors like type of work environment, especially for industrial workers. A recent study in South India indicated the prevalence of over 25 percent of job related stress in industrial workers, owing to severe working conditions (Mohan et al., 2008). Stress can be caused by environmental, organizational, and individual variables (Cook and Hunsaker, 2001). Organizational-based factors have been known to induce job stress for employees at the workplace (Greenhaus and Beutell, 1985). These factors are commonly termed as organizational stressors since they serve as agents that trigger the various stress reactions (Von Onciul, 1996).

Studies have been carried out on job stress in relation to various stressors, and mainly on role ambiguity, role conflict, physical work factors, and working environment. MacKinnon (1978) and Jamal (1984) have utilised role ambiguity, role conflict, and resource inadequacy as the measures of job stress. Role ambiguity refers to the degree to which employees are short of clarity about their role or the task stress at work (Spector, 2000). It occurs when an employee does not know or realize the prospect and demands of the job (Kahn and Cooper, 1993). Roberts et al. (1997) found the role conflict to have a positive relationship with job stress. When individuals are required to play two or more role requirements that work against each other, they are likely to experience job stress. This is because role conflicts create expectations that may be hard to reconcile. Working conditions/environment of job has been linked to mental health. It was found that poor psychological health related directly to disagreeable working conditions, physical-effort and speed in job performance (Osipow and Davis, 1998). Additionally, work environment associated with unpleasant organizational climate, lack of privacy, a lot of hassle in conducting work, and distractions can result in higher stress (Miller and Ellis, 1990; Eugene, 1999). Hicks et al. (2006) also utilized role ambiguity and working environment in a confirmatory factor analysis approach towards the analysis of occupational stress inventory among Australian teachers.

Role conflict and role ambiguity are among the antecedents of job stress which have been most cited in the research literature (Fisher and Gitelson, 1983). Role conflict, that is pressure to perform in two or more incompatible ways, has been tied conclusively to job stress in Western research. It has also been demonstrated to be a factor in job dissatisfaction and propensity to leave the organization one works for ever since the classic work of Kahn and his colleagues (Kahn et al, 1964). Role ambiguity, the lack of clear and specific information regarding work role requirements, has also been linked repeatedly with job stress and low job satisfaction (Cordes and Dougherty, 1993).Since role conflict and role ambiguity are issues in most Western organisations, they must be faced by Indian workers as well.

Typical research on stress in the workplace, consistent with Kahn et al. (1964), has focused on chronic stressors assumed to be common to all jobs, such as the existence of role ambiguity and role conflict. Studies support theoretical notions that social support can aid stress resistance by supplying people with the information that they are loved, appreciated, and part of a network of caring individuals (Cobb, 1976).

Sharma (1985) examined the role of institutions in promotion of health and psychological well-being by looking at different component measures at the cross-national and the cross-cultural levels. Results suggested that social support played an important role in affecting variables such as stress and mental well-being. Teja (1978) studied the relationship between the family support system and emotional problems. He concluded that in general the higher incidence of adjustment reactions and personality disorders in American patients was related to the cultural emphasis on individualism and role adequacy. He attributed the relatively lower incidence of these conditions in Indian patients to the mutuality, interdependence, and cohesiveness of the family support system that prevail among family members in Indian families.

2.2.4 Work-Related Musculoskeletal Disorders

Musculoskeletal Disorders (MSD) are injuries affecting muscles, tendons, ligaments and nerves. They are sometimes called Repetitive Strain Injuries (RSI), Cumulative Trauma Disorders (CTD) and Repetitive Motion

Injuries (RMI). MSD develop due to the effects of repetitive, forceful or awkward movements on joints, ligaments and other soft tissues. Some MSD injuries include Low Back Strain, Neck Strain, Tendonitis, Carpal Tunnel Syndrome (CTS), Rotator Cuff Syndrome, and Tennis Elbow. There has been an increasing effort in recent years to investigate Musculoskeletal disorders (MSDs) and to take action to prevent them. This has led to increasing recognition from workers, employers and government agencies that a strong relationship exists between factors within the working environment and the development of MSDs, and that these conditions result in significant sickness absence and reduced productivity (Buckle and Devereux, 1999).

MSDs constitute a major public health problem in the industrialized countries. MSDs cause individual suffering, trouble in daily living, and considerable economic and societal consequences due to short- and long-term work disability and productivity losses (Buckle, 2005). Low back pain, neck pain and shoulder disorders are common among working populations and are the main reasons for work-related consultations in general practice (Weevers et al., 2005).

2.2.5 Job Stress and Work-Related Musculoskeletal Disorders

The association between work stress and musculoskeletal pain and disorders (MSDs) is well established. A review by Bongers et al. (1993) was one of the first to confirm a possible relationship between psychological factors and MSDs. In 1997, NIOSH identified work stress as a “significant and independent” risk factor for MSDs. Most recently, the National Research Council (NRC) found a positive association between monotonous work, intensified workload, time pressure, heavy job demands and lack of job control and incidence of these disorders.

Work-related musculoskeletal disorders (WRMSDs) have emerged as major health problem among workers in both industrialized and industrially developing countries (Westgaard and Winkel, 1997). Several work place factors, such as repetitive work, awkward and static postures, have been identified as being associated with upper extremity pain and discomfort (Punnett et al., 2000). Physical and psychosocial load, poor climatic conditions, and vibrations have been identified as risk factors that contribute to developing MSDs among workers (Hildebrandt, 1995). Psychosocial risk factors for work-related MSDs can be categorised into those that are specific to the workplace (low social support at work, job satisfaction, low skill discretion, low job control etc.) and those that are individual psychosocial or psychological characteristics, such as depression, anxiety and mental stress (National Research Council, 2006). Non-workplace factors, which contribute to work-related MSDs possibly influencing individual responses to workplace exposures, are considered as individual factors.

Work disability related to MSDs or WRMSDs is a challenge to employability, business productivity, and the capacity of health and social security systems (BLS, 2004 and NIOSH, 2001). In many countries the prevention of work-related musculoskeletal disorders has been considered as a national priority. Absents from work and work lost days is one of the most important problems within the scope of industrial hygienists.

2.3 Job Stress and Work-Related Musculoskeletal Disorders Research

This section reviews the literature related to job stress and work-related musculoskeletal disorders research. This section includes the taxonomy of research related to job stress inducing factors, and that of work-related musculoskeletal disorder research. The taxonomy of literature for work-related musculoskeletal disorder research is depicted in Table 2.1.

Table 2.1: Taxonomy of Literature for Work-Related Musculoskeletal Disorder Research

Sl No.	Work Systems	References
1	Software Industry	Silvian and Maiya (2011)
2	Heavy Industry	Bertha (2011), Joshi and Menon (2001)
3	Automotive Industry	Spallek and Kuhn (2010)
4	Forging Industry	Singh and Lal (2012)
5	Weaving Industry	Nag and Vyas (2010)
6	Construction Workers	Bodhare and Valsangkar (2011)
7	Farm Workers	Singh and Arora (2010)
8	Goldsmiths	Ghosh and Das (2010)

The taxonomy of literature for job stress inducing factors is depicted in Table 2.2.

Table 2.2: Taxonomy of Literature for Job Stress Inducing Factors

Sl No.	Job Stress Factors	References
1	Role Ambiguity	Kahn et al. (1964) , Ram &Khoso (2011)
2	Role Conflict	Kahn et al. (1964) , Ram &Khoso (2011)
3	Physical Work Factors	Crawford & Bolas (1996) , Chen (2005)
4	Working Environment	Michie (2002) , Thomas &Colligan (2006)
5	Social Support	Beehr& Drexler (1986)
6	Decision latitude	Warr (2007) , Bhagat& Krishnan (2010)
7	Threat of Physical Harm	Warren (2001) , Kiani&Samavtyan (2012)
8	Additional Responsibilities	Michie (2002) , Sirajunisa&Panchanatham (2011)
9	Neuroticism	Eysenck & Eysenck (1985)
10	Rumination	Roger & Najarian (1998)
11	Job Satisfaction	Hurrell & McLaney (1988)
12	Job Future Ambiguity	Hurrell & McLaney (1988)
13	Supervisor Support	De Lange et al(2004)

2.4 Research Gaps Identified

From the review of literature the following research gaps were identified.

1) There doesn't exist an instrument framework for measuring the job stress in chemical process industries in India, and specifically for those in the Indian state of Kerala.

2) Systems consist of feedbacks and safety systems are no exception. The existing models for job stress and musculoskeletal disorders have not effectively captured the feedbacks in the system which could have considerable effects on the system behaviour over time.

2.5 Conclusions

This chapter has presented a detailed survey of literature on job stress and its effects, the growth of research in job stress in the world, and the work related musculoskeletal disorders in industries. The following chapter presents the detailed methodology followed in this thesis on work-related musculoskeletal disorders – job stress system in chemical process industries in India.

Chapter 3

RESEARCH METHODOLOGY

Contents

3.1 Introduction

This chapter provides a detailed methodology followed in this research on job stress and its influence on work-related musculoskeletal disorders in chemical process industries in Kerala, India. This chapter is aimed to present the current methods adopted in the present research.

3.2 Methods Adopted in the Present Research

The present research work includes methods like questionnaire surveys, multivariate statistical modeling which includes exploratory factor analysis and confirmatory factor analysis, system dynamics modeling and policy planning. These methods are discussed in detailed in the following sections.

3.2.1 Conducting Questionnaire Surveys

A survey is defined as the systematic procedure of collecting data from the population of interest. The aim of the survey is to collect quantitative data from a sample which is the true representation of the population. This aim is accomplished through the use of a structured questionnaire survey.

The data can be categorized into primary, secondary and tertiary data. The primary data is the most important and indispensable in doing successful research. Acquiring of primary data is costly and time consuming in nature, whereas secondary and tertiary data are easily procurable but may not meet the research purpose. A questionnaire survey is the method of collecting primary data in its most reliable manner (Janes, 1999; Menon and Mahanty, 2013).

The questions for the survey have to be carefully designed and hence it is a meticulous process. The questionnaire should also be tested for ensuring that they meet the purpose. Standard questionnaires are usually available from institutes, published articles and research organizations, and which are found to be directly utilized for surveying. In such situations, care should be made to ensure that the standard questions used are valid in the context of a particular country and the related issue addressed. To ensure the same, a pilot survey is initially carried out to find out whether the survey questionnaire is rightly responding to the research purpose for which it is used.

There exist three different methods of administering the questionnaire which are classified as closed-ended, open-ended and a combination of the two (McClelland, 1994). Closed-ended questionnaires are used when the responses are known or certain. The respondents are to choose from the set of known alternatives provided to them. This type of questionnaire consists of questions of the nature of yes or no type, filling the blank type, ranking type, or multiple choice types. Open-ended questionnaire involves collecting the information that is otherwise missed in closed-ended type questions (Geer, 1991). In this type, the respondents are to answer the questions in their own words, which are in turn intended to capture the information in the minds of the respondents. These are usually utilized when there is no known hypothesis existing regarding the research issue addressed (Menon and Mahanty, 2013). For the present research work, a closed-ended questionnaire is utilized.

3.2.2 Multivariate Statistical Modeling

The generic tool of multivariate statistical analysis has wide applications in the broad fields of sociology, psychology, heath care, tourism, management science, and various systems modeling. Factor analysis is a set of statistical techniques that are used to explore and confirm the underlying structure of the data corresponding to a set of variables/items. In doing so, they determine those variables/items that tap a factor or latent construct (Dyer et al., 2005; Hair et al., 1998). Factor analysis is divided into two parts namely, exploratory factor analysis and structural equations modeling. The latter is further divided into the statistical methods of path analysis and confirmatory factor analysis. The exploratory factor analysis brings out the underlying structure of the data thereby exploring the factors that are explained by the variables/items. The underlying structure identified through the exploratory modeling is confirmed through structural equations modeling technique of confirmatory factor analysis (Nunnally and Bernstein, 1994). Software like SPSS, MINITAB and AMOS are utilized to perform the factor analysis techniques.

3.2.2.1 Exploratory Factor Analysis

Exploratory factor analysis (EFA) is widely utilized to explore the underlying structure of a set of observed variables (Child, 1990). EFA is basically a data reduction technique. The objective is to condense the information contained in a number of original variables into a small set of factors with a minimal loss of information (Hair et al., 1998).

The unobservable characteristics are not directly measurable, but are instead latent variables, with observed measures being their indicators in concealed behaviour (Raykov and Marcoulides, 2008). These unobservable characteristics factors can be measured through some observable variables which can be tapped through the questionnaire surveys. Thus, the purpose of EFA is to identify the underlying factor structure of the data. This involves the factor extraction and factor loadings of each attributes on to a factor.

3.2.2.2 Confirmatory Factor Analysis

Structural equation modeling (SEM) is a technique to estimate, and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables (Shah and Goldstein, 2006). SEM models consist of observed variables and unobserved variables (latent variable) that can be independent (exogenous) or dependent (endogenous) in nature. Structural equation modeling is useful in inferential data analysis and hypothesis testing where the pattern of interrelationships among the study constructs are specified a priori and are grounded in established theory (Hoe, 2008).

Confirmatory factor analysis (CFA) is a special case of structural equation modeling. In confirmatory factor analysis, one is not concerned with discovering the underlying factors as in EFA, but instead with quantifying, testing, and confirming an a priori proposed or hypothetical structure of the relationships among a set of considered measures (Raykov and Marcoulides, 2008). To accomplish this aim, CFA requires that unobserved variables (or factors or latent variables) and their associated observed variables (or manifest variables) be specified before analyzing the data (Hair et al., 1998; Shah and Goldstein, 2006). The outcome of confirmatory factor analysis is used to examine the fit of the proposed measurement model (Torkzadeha et al., 2005). To sum up, CFA is a theory or hypothesis testing procedure (Menon and Mahanty, 2013).

The exploratory factor analysis and structural equation modeling have been utilized by some researchers in modeling job stress all over the world. Hamel and Bracken (1986) used factor analysis to analyze the internal consistency and factorial composition of the job stress questionnaire and to compare its factor structure across three occupational groups. The factorial composition of the job stress questionnaire and its internal consistency were examined using structural equations modeling by Harris et al. (1999). Sager (1994) developed and tested a model of sales people’s job stress relative to its proposed determinants and outcomes. Jonge et al. (2001) examined the reciprocal relationships between job characteristics and work-related psychological well-being of health care professionals using structural equation modeling. Van Dick and Wagner (2001) tested the theoretical model of teacher stress on a large sample using structural equation statistics. Elangovan (2001) studied the confusion prevailing over the nature of the relationship between satisfaction and commitment in regard to employee turnover based on the causal pattern of relationships among stress, satisfaction, commitment, and turnover intentions by employing a structural equations analysis approach. Lange et al. (2004) tested their hypotheses concerning the causal relationships between job demands, job control and supervisor support among a heterogeneous sample of Dutch employees using structural equation modeling. Still there exists a vast pool of literature on the utilization of factor analysis techniques in developing and testing models concerning job stress. This vast literature shows the suitability of factor analysis techniques in safety systems and job stress modeling.

3.2.3 System Dynamics Modeling

System dynamics is a method of analyzing system related problems in which time is an important factor and involves the study of how a system can be defended against or benefited from the shocks that falls upon it from the external world (Coyle, 1977). It is rooted in feedback control theory and nonlinear dynamics. System dynamics is used to capture the feedback structure of the system which gives rise to the behaviour of the system over time and aids in carrying out policy experimentation.

System dynamics, as a methodology, has the capability to capture the delays, non-linearities and the soft components present in the system. System dynamics is an approach, which considers the causal mechanisms of reality and uses quantitative means to investigate the dynamic behaviour of the real world system and its responses to policy decisions. Policy experimentation can be carried out by making appropriate changes in the structure, model parameters, or in the policies of the management. The dynamic behaviour generated through simulation reveals the changes in the key variables over a period of time. Thus, system dynamics helps in scenario-generation and in identifying suitable policies for the problem considered (Menon and Mahanty, 2013; Sterman, 2000).

The methodological frame work followed in system dynamics modeling in the present research is given in Table 3.1 below.

Table 3.1: Methodological Framework for System Dynamics Modeling (Adopted from Elias, 2012; Menon and Mahanty, 2013)

Phases	Steps
System dynamics modeling	Developing a causal loop diagram
	Defining variable types
	Constructing a stock and flow diagram
	Developing the simulation model
	Reproducing reference mode behaviour
	Validating the model
Model experimentation	Conducting the base run
	Modelling scenarios using the model
	Conducting policy experiments on the model

A causal loop diagram forms the initial step in system dynamics modeling. CLDs show the causal relations between the system entities through the use of text, arrows and symbols (Stepp et al., 2009). An arrow having its tail at the cause variable and its head at the affected variable represents the relations between them. The arrow head bears the causal link polarity. A positive polarity indicates that the perturbation in the causal variable is transmitted in the same direction to the effect variable and a negative polarity indicates that the perturbation in the causal variable is transmitted in the opposite direction to the effect variable provided *ceteris paribus*. The causal relations finally form feedback loops that are either reinforcing (R) or balancing (B) in nature. Thus a feedback loop or a causal loop can be positive or negative in nature. A positive loop, denoted as R-loop, reinforces the behaviour thereby reinforcing either growth or decline of the system. A negative loop, denoted as B-loop, is of balancing nature and tries to bring back the system to a desired state (Sterman, 2000).

Causal loop models are developed heuristically involving iterations. The adjacency matrix method is a way to develop the causal loop diagrams. The available literature is studied initially and is decomposed into a sequence of inferences. Nouns and adjective/noun forms in every inference are identified and integrated into a matrix to facilitate selection of variables and polarized relationships. This adjacency matrix is finally translated into the causal loop diagram (Ali and Ramaswamy, 1993; Camara, 1991; Menon and Mahanty, 2013). Thus developed causal loop diagram forms the input to the quantitative modeling that involves stock and flow diagrams which are in turn utilized to simulate the behaviour over time of the system under study.

3.2.4 Reference Mode Behaviour

The first step in the system dynamics modeling is to define the problem. This problem definition is named reference mode or behaviour over time chart. Therefore, a reference mode is a process of defining a problem for building a system dynamics model. Reference mode is based on historical information and is often described in a graphical form (Menon and Mahanty, 2013; Saeed, 1998; Sterman, 2000).

The reference mode behaviour is a tool used in systems thinking to depict the patterns of the key variables in a system over an extended period of time which usually spans from several months to years. The reference mode indicates the systemic behaviours of growth, decline, oscillations, or a combination of these behaviours (Elias, 2008). The reference mode is to capture the trends, directions and variations of key variables considered and are not supposed to be based on the numerical value of the variables. Therefore, these charts are drawn in a rough sense without any numerical values utilized (Elias, 2008; Maani and Cavana, 2000; Menon and Mahanty, 2013).

3.2.5 System Dynamics Model Validation

The appeal of SD models rests in its ability to capture the feedbacks in the systems which in turn forms the structure of the system. The system structure generates the systemic behaviour. Thus, it is important to ensure the capture of a correct system structure before the start of quantitative modeling (Gass, 1983; Menon and Mahanty, 2013; Sterman, 2000).

The work-related musculoskeletal disorders – job stress system is to have a direct impact on the day to day working of the chemical process industries in any country. For the same reason, the confidence in system dynamics model developed for simulating the work-related musculoskeletal disorders – job stress system becomes an important issue. System dynamics models are mainly built with an aim towards analyzing policies that can improve the behaviour of the system in the long run. The policies taken towards mitigating the concerned issues are of much importance as wrong policies can even result in a further deterioration of the system leaving observable negative impacts on the industry under study. Hence these policy outcomes should generate confidence in the stakeholders for them to accept those policies before implementation. Validation of the SD models can aid in this purpose (Menon and Mahanty, 2013).

3.3 Conclusions

This chapter has detailed on the research methodology followed in this thesis. The following chapters present the details of the research work carried out on the work-related musculoskeletal disorders – job stress system in chemical process industries in India.

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Chapter 4

MODELING AND DEVELOPMENT OF AN INSTRUMENT FRAMEWORK FOR MEASURING JOB STRESS IN CHEMICAL PROCESS INDUSTRIES IN INDIA

Contents

4.1 Introduction

In this modern complex world, stress at work/job is found to be increasingly a common feature in day to day life. For the same reason, job stress is one of the active areas in occupational health and safety research for over last four decades and is continuing to attract researchers in academia and industry (Edwards, 1992; Lamontagne et al., 2007; Zohar, 1994). Job stress is found to influence the workplace safety (Hayes et al., 1998; Noblet and Lamontagne, 2006; Rundmo, 1992), and effect the work-related musculoskeletal disorders (Caruso and Waters, 2008; Cox et al., 2000; Haukka et al., 2011; Jones et al., 1998; Lipscomb et al., 2002). Previous studies have shown that high job stress leads to low job performance (Jamal, 1984; Motowidlo et al., 1986; Westman and Eden, 1996); low job stress leads to high job performance (Keijsers et al., 1995);

and people with moderate job stress performs comparatively better than those with high or low levels of job stress (Anderson, 1976). Moreover, high job stress can lead to decreased job satisfaction resulting in increased turnover of the workers (Gray-Toft and Anderson, 1981).

Job stress in process industries is of concern due to its influence on process safety and worker‘s safety and health. Safety in process (chemical and nuclear material) industry is of paramount importance, especially in a thickly populated country like India. In process industry, safety is an operating characteristic and the safety concerns are of prime importance to these firms (Hofmann et al., 1995). Burk and Smith (1990) observe that nearly every accident may be traced to an employee’s unsafe act. In accident literature, “human error” (or human failure) can be seen as one of the main contributor to the process industry accidents. Kletz (1985) observes that in most of the chemical and oil industries, about 50 percent to 90 percent of industrial accidents were due to “human failing”. From an individual level, this “human failing” can occur due to the individual employee’s work or job related stress. Moreover work-related musculoskeletal disorders (WRMSD) can also be induced by job stress in workers. The study on the role of job stress on work-related musculoskeletal disorders can be traced back in the work of Kornhauser (1965). Later, Kuorinka (1979) studied the occupational strain caused by working movements in detail. Through a questionnaire survey, Jones et al. (1998) found that 26.6 percent of the respondents suffered from work-related stress, depression or anxiety, or a physical condition which they attributed to work-related stress. Further, the authors estimated that 19.5 million working days were lost in Great Britain due to work-related stress, of which 11 million were due to musculoskeletal disorders. Haukka et al. (2011) researched up on the job related mental stress and its relation to musculoskeletal pain in kitchen workers.

In view of the above reasons, the process industries should try to minimize the job stress in workers to ensure a safe and healthy working climate for the industry and the worker. Therefore, need exists to carry out studies in towards understanding and analyzing the influence of job stress on work-related musculoskeletal disorders chemical process industries in India. For the same, it is necessary to measure the level of job stress in workers using an "instrument". In this background, the current research aspires to bring to light the determinants of job stress in chemical process industries and to propose a comprehensive model and an instrument framework for measuring job stress in chemical process industries in the state of Kerala, India. Against this backdrop, a questionnaire survey was carried out followed by multivariate statistical modeling in order to bring to light the important factors that cause job stress in Indian chemical process industries. The study aims to answer the specific question of what are the factors that induce job stress in chemical process industries in India.

4.2 Materials and Method

4.2.1 Survey Instrument

From a review of related literature and theory, a 26 item questionnaire covering job conditions like the design of tasks, management style, interpersonal relationships, work roles, and environmental conditions was prepared. The questionnaire utilized for developing the job stress is mainly based on the questionnaire given by NIOSH (1998). The items included were those of individual and situational characteristics that can intensify the effect of stressful working conditions as cited by NIOSH. The content of the preliminary draft questionnaire was discussed with senior professionals from the selected 8 chemical process industries and senior professors in management studies to ensure face validity. Some of the items in the questionnaire were further modified through rewording, removing and replacing with more simplified form. Each item in the questionnaire was provided in English as well as in “Malayalam” which is the regional language in Kerala to ensure that the subjects clearly understood the meaning conveyed by the items. Necessary definitions of the technical terms were also provided in the questionnaire.

Initially, a pilot survey was conducted on a selected sample of 200 workers from eight process industries to get the feedback about the clarity of items. Those questionnaire items with item-to-total correlation below 0.15 were dropped from the instrument. Finally, after the pilot survey the number of items reduced from 26 to 20. The respondents were asked to give their preference on a 5 point Likert scale according to the level of their agreement to the statement asked. The questionnaire ready for administration consisted of two parts. The first part consisted of seven demographic questions which included the name of the company, designation, qualification, age, gender, marital status and work experience. The 20 statements related to job stress constituted the second part. To maintain anonymity, no questions related to name, badge number or signature was included in the questionnaire.

4.2.2 Sampling and Data Collection

When conducting questionnaire survey, one of the reasons for biased survey results is the incorrect response to the posed questions by the "subjects" due to their inability to interpret the correct meaning of the items included in the survey. This in turn can be attributed to the subject's less proficiency in English language. The present questionnaire survey was conducted in the state of Kerala in India. The state of Kerala is the most literate state in India and hence is found appropriate for conducting questionnaire survey with less bias. Eight large chemical industrial units in Kerala were selected for questionnaire administration; the details of which are depicted in Table 4.1. All the eight process industries were having three shifts per day that included 8 a.m to 4 p.m., 4 p.m. to 12 a.m., and 12 a.m to 8 a.m, of which the questionnaire was distributed personally to all the workers present in the first two shifts respectively. The researcher met the workers personally and explained the purpose of the study and answered any queries regarding the same from their side. The participation was voluntary. Completed questionnaires were personally collected from the participants and a total of 1197 completed forms were received with a response rate of 82 percent. It took a maximum of two weeks to complete the survey in each unit, and the whole data collection was completed in five months time. A large sample size of more than 1000 was used to ensure that it covered almost every worker eligible to participate in the survey thereby ensuring a complete cross-section. Table 4.2 lists the 20 items questionnaire administered to the respondents who are the workers in chemical process industries in the state of Kerala, India.

Table 4.1 Details of Organizations and Response Rates

Organisation	Owned by	Main Products	Questionnaire Survey Details		
			Distributed	Returned	% Response
1	Government of India	Caprolactam	200	163	82
2	Government of India	Ammonia, Sulphuric acid, Phosphoric acid, Ammonium phosphate, Ammonium sulphate and Factamfos	270	219	81
3	Government of India	Sulphuric acid, Phosphoric acid and Ammonium phosphate	120	106	88
4	Government of Kerala	Caustic soda, Liquid chlorine and Hydrochloric acid	250	197	79
5	Private	Zinc, Cadmium, and Sulphuric acid	210	172	82
6	Government of India	Phenol, Acetone and Hydrogen peroxide	120	105	88
7	Government of India	Petrochemicals	180	150	83
8	Government of Kerala	Titanium dioxide, Ilmenite, Rutile, Leucoxene, Zircon, Sillimenite and Monazite	120	85	71
Total			1470	1197	82

Table 4.2: The 20 Items Questionnaire

Questions Related to Worker's Role

Q1. I know clearly how much authority I have.

Q2. There are clear, planned goals and objectives for my job.

Q3. I know clearly what is expected of me.

Q4. I have to bend or break a rule or policy in order to carry out an assignment.

Q5. I work with two or more groups who operate quite differently.

Q6. I receive incompatible requests from two or more people.

Q7. I receive an assignment without the help I need to complete it.

Questions Related to Working Environment

Q8. The level of noise in the area(s) in which I work is high.

Q9. The level of lighting in the area(s) in which I work is low.

Q10. The temperature of my work area(s) is high.

Questions Related to Worker Safety

Q11. How often your job does require you to work very fast?

Q12. How often does your job require you to work very hard?

Q13. Do you have to sit on a chair or stool for one hour or more without a break?

Q14. Do you use keyboard for more than one hour a day?

Q15. In the past twelve months, I have been restricted from doing my routine job at least once due to some disabilities.

Q16. In the past twelve months, my job has been a vector for my disability/disabilities

Questions Related to Support to and Responsibility for the Worker

Q17. How much can your immediate supervisor (boss) be relied on when things get tough at work?

Q18. How much can your spouse, friends and relatives be relied on when things get tough at work?

Q19.I have to do child care duties apart from my routine job.

Q20.I have the primary responsibility for the care of elderly parents or disabled person on a regular basis.

4.2.3 The Data

A total of 20 questions were administered to the respondents who are the workers from chemical process industries in India. The first seven questions (Q1 to Q7) were related with the worker's role in the job floor. The questions Q8 to Q10 were related to the working environment in the chemical process industry. The questions Q11 through Q16 were to capture the worker's concerns of his safety in the chemical process industries in India. The support for the worker and work's responsibilities were captured through the questions from Q17 to Q20.

4.3 Results - Structure of Job Stress

Using the collected data through the questionnaire survey, a measurement framework was developed for the job stress in chemical process industries in India. For the same, initially underlying structure of job stress was brought out from the collected data using exploratory factor analysis; followed by confirming the underlying structure thus obtained through confirmatory factor analysis. This is followed by standardizing the measurement scale developed to ensure that the scale actually measures what it is supposed to measure (Sureshchandar et al., 2001). For the same, validity of the scale is established finally.

4.3.1 Data Analysis and Results

The underlying structure of the collected data was explored using exploratory factor analysis (EFA). The extracted factor structure was utilized in developing the structural equations model. The structural equations model developed was validated to reflect the data structure obtained through the exploratory analysis through the goodness of fit statistics like chi-square/degrees of freedom, root mean square error of approximation (RMSEA), comparative fit index (CFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI) and Tucker-Lewis index (TLI) (Vinodkumar and Bhasi, 2009).

4.3.2 Exploratory Factor Analysis

Exploratory factor analysis is a statistical technique to uncover the underlying structure of the data. Exploratory factor analysis extracts out the variables that are interdependent to form factors (Dyer et al., 2005).

The data collected through questionnaire survey for 20 variables was subjected to exploratory factor analysis with the method of principal component factor extraction using SPSS 12.0 package. The data was subjected to exploratory factor analysis to identify the underlying latent variables that emerge from the survey.

4.3.2.1 Initial Data Validity Test

Kaiser-Mayer-Olkin (KMO) test is performed to check the adequacy and validity of the descriptive statistics. A KMO value of 0.5 or less is considered to be unacceptable (Bryman and Cramer, 1999) while higher value tends to improve the value of each variable. The results of KMO test of sample adequacy and the Bartlett's test of sphericity are presented in Table 4.3. The Kaiser-Mayer-Olkin measure of sampling adequacy was 0.773 while the Bartlett test of sphericity resulted in a value of 4839.897 with a p-value of less than 0.05 thereby satisfying the assumption of data being multivariate normal.

Table 4.3: KMO and Bartlett Test

KMO Sample Adequacy	Bartlett's test of Sphericity		
	App. Chi-square	df	Significance
0.773	4839.897	190	0.000

4.3.2.2 Factor Extraction

The data was subjected to exploratory factor analysis (EFA) with principal component factor extraction method. The initial unrotated component solution matrix obtained using SPSS 12.0 software is shown in Table 4.4. It can be noticed from the table that eight factors are extracted. Along the columns we have eight factors, while along the rows are the 20 attributes. The entry in the cell (Cij) corresponds to the factor loading of the variable (Vi) on the factor (Fj), in essence Cij are the correlations coefficients between Vi and Fj.

Table 4.4: Initial Component Matrix (Eight Factors, without Rotation)

Variables (Vi)	Component (Fj)							
	1	2	3	4	5	6	7	8
Q3	.863	.055	.015	.269	-.028	.035	.075	.228
Q2	.846	.081	-.023	.278	-.034	.051	.161	.240
Q1	.810	.115	-.162	.283	-.041	.016	.086	.200
Q14	-.635	-.072	.044	.127	.029	-.022	.475	.152
Q6	-.521	.345	.123	.109	-.048	.191	-.197	.095
Q8	.237	.544	.136	-.463	.143	-.086	.010	.049
Q10	.306	.514	.094	-.438	.120	-.108	.042	.066
Q4	-.175	.477	.076	.288	-.100	.235	-.323	.105
Q7	-.358	.414	.167	.326	-.090	.056	-.031	.092
Q9	-.041	.392	.088	-.385	.066	-.196	-.028	.254
Q12	-.145	.269	-.548	.138	.531	-.052	-.054	-.111
Q11	-.146	.195	-.540	.250	.521	-.122	.090	-.046
Q16	.084	-.223	.524	.069	.480	.249	-.195	.118
Q17	.108	.333	.432	.307	.080	-.364	.071	-.288
Q5	-.298	.280	-.067	.334	-.172	.143	-.264	.145
Q15	.060	-.213	.401	.007	.582	.359	.037	.061
Q19	.202	.182	-.167	-.028	-.108	.552	.182	-.444
Q20	-.045	.343	-.003	-.195	-.079	.499	.456	-.064
Q13	-.510	.033	.140	.187	.008	-.131	.516	.362
Q18	.148	.193	.394	.306	.015	-.247	.163	-.522

Extraction Method: Principal Component Analysis.
Components Extracted: 8 components extracted.

The present factor extraction is carried out using the method of Eigen values. Here the number of factors extracted is based on the Eigen values equal to or greater than one. The solution depicted in Table 4.4 has low factor interpretability. A varimax rotation was carried out to enhance factor interpretability, and the rotation converged in 6 iterations. The factor loading cut-off was fixed at 0.4 which is an accepted cut-off in exploratory and confirmatory research (Hair et al., 2005; Vinodkumar and Bhasi, 2010). The final rotated and sorted component matrix is given in Table 3.5. Finally an 8 factor structure was extracted out with an Eigen value greater than 1 which explained 64.465 per cent of the total variance. Thus the questionnaire items that measures similar characteristics are loaded together under each factor. Thus a factor represents correlated variables that are supposed to measure it indirectly.

Table 4.5: Final Sorted Component Matrix (Eight Factors, with Rotation)

Variables	Component							
	1	2	3	4	5	6	7	8
Q2	.922							
Q3	.907							
Q1	.883							
Q4		.714						
Q5		.622						
Q6		.606						
Q7		.590						
Q8			.758					
Q10			.732					
Q9			.617					
Q13				.832				
Q14				.724				
Q11					.833			
Q12					.832			
Q15						.812		
Q16						.803		
Q18							.808	
Q17							.758	
Q19								.752
Q20								.715

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 6 iterations.

Total of 8 factors were extracted which were role ambiguity (F1)**,** role conflict (F2), working environment (F3), physical work factors (F4), decision latitude (F5), threat of physical harm (F6), social support (F7) and additional responsibilities (F8). The extracted 8 factors with their names (F1-F8) and the corresponding questionnaire items (20 items) along with the item indicators (F1: Q1-Q3, F2: Q4-Q7, F3: Q8-Q10, F4: Q11-Q12, F5: Q13-Q14, F6: Q15-Q16, F7: Q17-Q18 and F8: Q19-Q20) are given in Table 3.6.

Table 4.6: EFA Results Showing Factor Name and Loaded Items with Item Indicators

F1. Role Ambiguity (RA) Q1. I know clearly how much authority I have. Q2. There are clear, planned goals and objectives for my job. Q3. I know clearly what is expected of me.
F2. Role Conflict (RC) Q4. I have to bend or break a rule or policy in order to carry out an assignment. Q5. I work with two or more groups who operate quite differently. Q6. I receive incompatible requests from two or more people. Q7. I receive an assignment without the help I need to complete it.
F3. Working Environment (WE) Q8. The level of noise in the area(s) in which I work is high. Q9. The level of lighting in the area(s) in which I work is low. Q10. The temperature of my work area (s) is high.
F4. Physical Work Factors (PWF) Q11. Do you have to sit on a chair or stool for one hour or more without a break? Q12. Do you use keyboard for more than one hour a day?
F5. Decision Latitude (DL) Q13. How often your job does require you to work very fast? Q14. How often does your job require you to work very hard?
F6. Threat of Physical Harm (TPH) Q15. Within the past 12 months, has the kind or amount of work you can do been limited by disability? Q16. Was this disability caused by your job?
F7. Social Support (SS) Q17. How much can your immediate supervisor (boss) be relied on when things get tough at work? Q18. How much can your spouse, friends and relatives be relied on when things get toughat work?
F8. Additional Responsibilities (AR) **Q19.**I have to do child care duties apart from my routine job. **Q20.**I have the primary responsibility for the care of elderly parents or disabled person on a regular basis.

From the developed 8 factor structure, the factors “role ambiguity” (F1: RA) and “role conflict” (F2: RC) captures the role of workers in job floor. The factors “working environment” (F3: WE) and “physical work factors” (F4: PWF) captures the working environment in the chemical process industry. The factors “decision latitude” (F5: DL) and “threat of physical harm” (F6: TPH) captures the safety concerns of the process industry workers. Finally the factors of “social support” (F7: SS) and “additional responsibilities” (F8: AR) captures the support for and the responsibilities of the workers in chemical process industries in India. The items loaded under each factor (item indicators), their factor loadings, factor variance explained and reliability coefficients are depicted in Table 4.7.

4.3.2.3 Reliability of the Scale Developed Through Exploratory Analysis

Reliability of an instrument is the extent to which all the items within the instrument measure the same on repeated trials; and Cronbach’s alpha is designed to measure the same internal consistency (Cronbach, 1951; George and Mallery, 2009). Out of various methods used for measuring reliability, the internal consistency method is considered to be the most effective method, especially in field studies (Vinodkumar and Bhasi, 2009). A Cronbach alpha (α)value of 0.70 or above is considered to be the criterion for demonstrating strong internal consistency of established scales (Nunnally, 1978). In the case of exploratory research, ‘α’value of 0.60 or above is also considered as significant (Hair et al., 1998; Vinodkumar and Bhasi, 2010). The Cronbach’s alpha for internal scale reliability for the exploratory analysis was estimated as 0.70; and that for eight individual factors to be more than a value of 0.65 (Table 4.7) which is above the acceptable limit of 0.6 for exploratory research. Hence, the job stress scale developed exhibits a good degree of reliability.

Table 4.7: Results of Factor Analysis Showing Factor Name, Loaded Item Indicators, Standardized Factor Loadings, % Variance Explained and Cronbach Alpha (α)

Factors (F1-F8)	Questionnaire items	Item indicators	Standardized factor loadings	% variance explained	Cronbach Alpha (α)
F1: Role Ambiguity (**RA**)	Q1 Q2 Q3	RA1 RA2 RA3	0.883 0.922 0.907	17.899 %	0.628
F2: Role Conflict (**RC**)	Q4 Q5 Q6 Q7	RC1 RC2 RC3 RC4	0.714 0.622 0.606 0.590	9.210 %	0.676
F3: Working Environment (**WE**)	Q8 Q9 Q10	WE1 WE2 WE3	0.758 0.617 0.732	7.675 %	0.689
F4: Physical Work Factors (**PWF**)	Q11 Q12	PWF1 PWF2	0.833 0.832	6.206 %	0.658
F5: Decision Latitude (**DL**)	Q13 Q14	DL1 DL2	0.832 0.724	7.297 %	0.693
F6: Threat of Physical Harm (**TPH**)	Q15 Q16	TPH1 TPH2	0.812 0.803	5.752 %	0.691
F7: Social Support (**SS**)	Q17 Q18	SS1 SS2	0.758 0.808	5.359 %	0.706
F8: Additional Responsibilities (**AR**)	Q19 Q20	AR1 AR2	0.752 0.715	5.065 %	0.692

4.3.3 Development of Structural Equation Model

The study utilized structural equation modeling for confirming the underlying data structure obtained through exploratory modeling. The AMOS software package for structural equations modeling was utilized for this purpose. The aim of this analysis was to test whether the factor structure obtained in the exploratory factor analysis was reflected in the collected data thereby confirming the obtained structure.

For the structural equations modeling, the most common estimation technique of maximum likelihood estimation (MLE) was used. MLE method requires the endogenous variables to be jointly multivariate normal distributed and, therefore, distributed normal individually. A utility in AMOS software helps to calculate the critical ratio of the multivariate kurtosis for variables and which is also known as Mardia's coefficient (Mardia, 1970). The multivariate kurtosis values less than one indicate negligible non-normality, 1 to 10 indicates moderate non-normality, and greater values indicate severe non-normality (Ory and Mokhtarian, 2009). In this study, the variables of study had a critical ratio of the kurtosis to vary between -1.3 and 5 which shows the data to be multivariate normal.

The developed structural equations model is depicted in Figure 4.1. The observed variables, which are the questionnaire items (item indicators), are shown as boxes while the latent variables, which are factors, are shown as ovals in the model. Each latent and observed variable are having a certain degree of error associated with it which was included in the analysis but are not shown in the Figure 4.1.

To assess the quality of model specification, we have considered goodness of fit indices like chi-square/degrees of freedom, root mean square error of approximation (RMSEA), comparative fit index (CFI), normed fit index (NFI), relative fit index (RFI) and incremental fit index (IFI). The RMSEA and CFI indices were used as these two indices were recommended because of their sensitivity to model misspecification (Bandalos, 2002; Hu and Bentler, 1999). The acceptable ranges for the indices used are adopted from Ory andMokhtarian (2009). From Table 4.8, it is evident that the model fitted the data well.

Table 4.8: Goodness-of-Fit Measures for the Structural Equations Model

Goodness-of-fit measures	Goodness-of-fit for the proposed model	Acceptable limits
Chi-square/degrees of freedom, χ^2/df	3.216	0.02 – 4.80
Root mean square error of approximation (RMSEA)	0.046	0.00 – 0.13
Comparative fit index (CFI)	0.922	0.88 – 1.00
Normed fit index (NFI)	0.892	0.72 – 0.99
Relative fit index (RFI)	0.890	0.78 – 0.91
Incremental fit index (IFI)	0.923	0.88 – 0.98

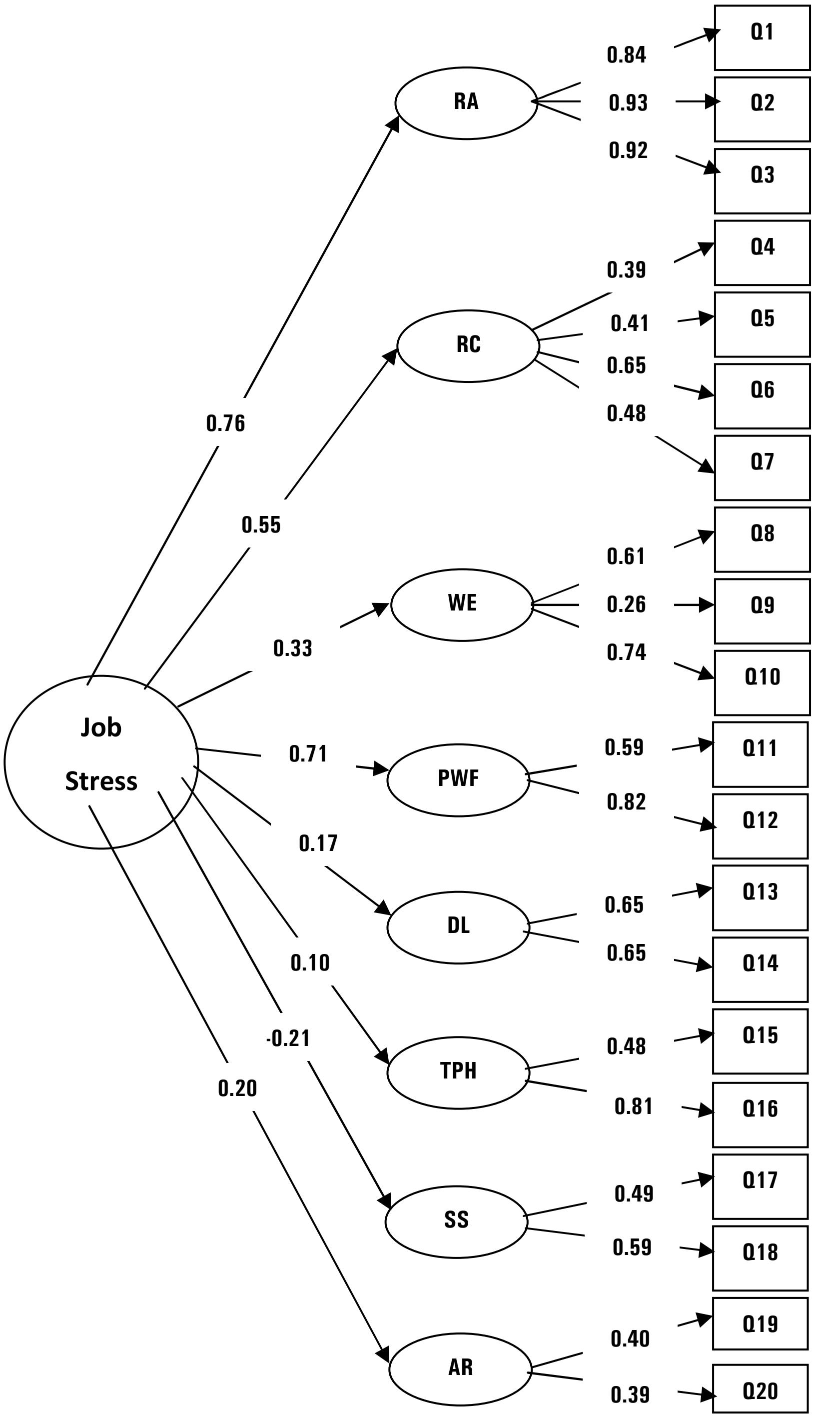

Figure 4.1: Complete Structural Equations Model Developed

4.4 Conclusions

This study was conducted in the developing country India as an attempt towards identifying the determinants of job stress and to develop an instrument framework for measuring job stress in chemical process industries in the country. The study uncovered eight factors (or dimensions) of role ambiguity (RA), role conflict (RC), working environment (WE), physical work factors (PWF), decision latitude (DL), threat of physical harm (TPH), social support (SS) and additional responsibilities (AR) to influence job stress in chemical process industries in India. It was also revealed that the four factors of role ambiguity, role conflict, working environment and physical work factors as the main inducers of job stress in chemical process industries in the country. From our study, it is found that the job stress in employees in Indian chemical process industries is most influenced by role ambiguity (RA) and the least by threat of physical harm (TPH). Not the least, role conflict, physical work factors and working environment are also to considerably influence the job stress in chemical process industries in the country. Thus the job stress in Indian chemical process industries can be conceptualised as an eight dimension structure composed of these above identified eight dimensions.

The developed instrument thus standardised can be used to measure the levels of job stress in chemical process industries in India. A job stress level index (JSLI) with respect to each dimension can be computed for every chemical process industries in India. The job stress level index (JSLI) for a particular chemical process industry with respect to a particular dimension is the average value of that dimension score per item. The JSLI is an indication of the job stress level in a chemical process industry with respect to a particular dimension. These can be the reference points for the decision makers in the chemical process industry upon which the job stress mitigation efforts should be targeted.

The management implication of this study is straight forward. The eight job stressors identified in chemical process plants through the present study can be mitigated through management activities. This in turn implies that the management can take actions that can effectively bring down these job stressors. Towards this, the management should find time and put effort to understand how these identified eight dimensions could be reduced for alleviating the worker's job stress related health problems. The developed job stress instrument can be used to evaluate the level of job stress in chemical process industries in India at any point of time and to devise management activities towards mitigating the same. Moreover, the instrument can be used as a benchmark tool for different chemical process industries and even for departments in a chemical process industry to compare the state of job stress prevailing.

4.5 Summary of this Study

The summary of this study are given below.

1. Exploratory factor analysis revealed the underlying structure of the data through the extraction of eight factors characterizing the job stress in chemical process industries in India. They are: 1) role ambiguity, 2) role conflict, 3) physical work factors, 4) work environment, 5) decision latitude, 6) threat of physical harm, 7) social support, and 8) additional responsibilities.

2. Confirmatory factor analysis has confirmed the data structure extracted through exploratory analysis that has increased the confidence in the dimensions extracted out. Thus, these identified dimensions are distinct and have practical significance.
3. The factor of role ambiguity was found to be the most influential and threat of physical harm to be the least influential on the job stress in chemical process industries in the country.
4. The factors of role conflict, physical work factors and work environment were also found to have considerable influence on inducing job stress in chemical process industries in India.

Chapter 5

EFFECT OF JOB STRESS IN INDUCING WORK-RELATED MUSCULOSKELETAL DISORDERS IN CHEMICAL PROCESS INDUSTRIES IN INDIA-A FEEDBACK LOOP STUDY

Contents

5.1 Introduction

The job stress is discussed widely as it is of concern over increasing work-related musculoskeletal disorders in workers in chemical process industries in India. The penalties of stress include health harms and reduction in work success. It pressure negatively on the organization and the individual's physical and mental system. This could result in summary performance, absenteeism, accidents, unprincipled behaviour, displeasure and sickness. Continued high levels of stress can direct to serious health circumstances including hypertension cancer, and psychological illnesses such as sadness or collapse (Palmer et al., 2003). According to Kyriacou (1989), symptoms of stress in workers are manifested in frustration, damage performance, and split relationships at work and at home. Researchers agree that a certain extent of stress is a usual part of life, but prolonged stressors could lead to signs that are physical, psychological or behavioural (O'Driscoll and Beehr, 2000).

The studies of job stress influence on work-related musculoskeletal disorders are widely researched around the globe. Still these studies are scarce in India in general and in Indian chemical process industries in particular. Analysing the impacts of workplace job stress are difficult as safety system comprised of job stress and musculoskeletal disorders involve a number of interconnected feedback processes leading to complexity in the system. Understanding and modeling the dynamics of this system is important for providing realistic and usable input to decision making towards the mitigation of musculoskeletal disorders induced by workplace job stress.

All systems consist of variables that are interlinked between themselves in the form of cause-effect relationships. These interlinked variables or the feedbacks between the variables together form the "structure" of the system (Menon and Mahanty, 2012). Similarly, the entities in the energy system interact with each other which give rise to the dynamic behaviour of the system. System structure can aid in understanding these interdependences and the system behaviour. There is a need for tools that can help policymakers understand these feedback effects. System dynamics is one such tool designed to understanding such feedbacks in the system (Sterman, 2008). Feedback loop diagrams or causal loop diagrams, rooted in system dynamics methodology, are used to capture the underlying structure of a system. They map the causal links, existing among the variables of the system, with arrows leaving from the cause and ending at the effect. A feedback loop or a causal loop can be positive or negative in nature. A positive loop, denoted as R-loop, reinforces the behaviour thereby reinforcing either growth or decline of the system. A negative loop, denoted as B-loop, is of balancing nature as it tries to bring back the system to a desired state. It is suggested that the causal loop diagrams can also be used without simulation for problem solving (Sterman, 2000).

In this chapter, a conceptual modeling framework is developed to capture the feedback loops appropriate for assessing the influence of job stress in inducing work-related musculoskeletal disorders in chemical process industries in India. These feedback loops are utilized to capture the interconnectedness amongst the variables in the work-related musculoskeletal disorder – job stress system in relation to the Indian chemical process industries under study. The causal relationships developed in the feedback loop model were based on the available knowledge about the real system, outcomes of the structural modeling efforts and the insights from the literature reviewed. The developed feedback loop model captures the dynamic interactions between variables in the system considered which include the job stress, its factors of role ambiguity, role conflict, physical work factors, work environment, absenteeism and job involvement. This feedback loop study is aimed at understanding the causal influence of job stress and its associated factors have on the work-related musculoskeletal disorders in chemical process industries in India with the help of system dynamics (SD) tools. This chapter presents in detail the qualitative analyses of the feedback loops present in the system considered.

The causal relationships developed in the feedback loop model were based on the available knowledge about the real system, the insights from the job stress and musculoskeletal disorders related literature reviewed, and the outcomes of the structural modeling (confirmatory factors analysis) efforts as presented in earlier chapters.

5.2 Defining Model Boundary and Developing Reference Mode Behaviour

A subsystem diagram for the musculoskeletal disorder - job stress system is presented in Figure 5.1. It shows the key variables that are considered in the present modeling. A model boundary chart for key variables is presented in Table 5.1.

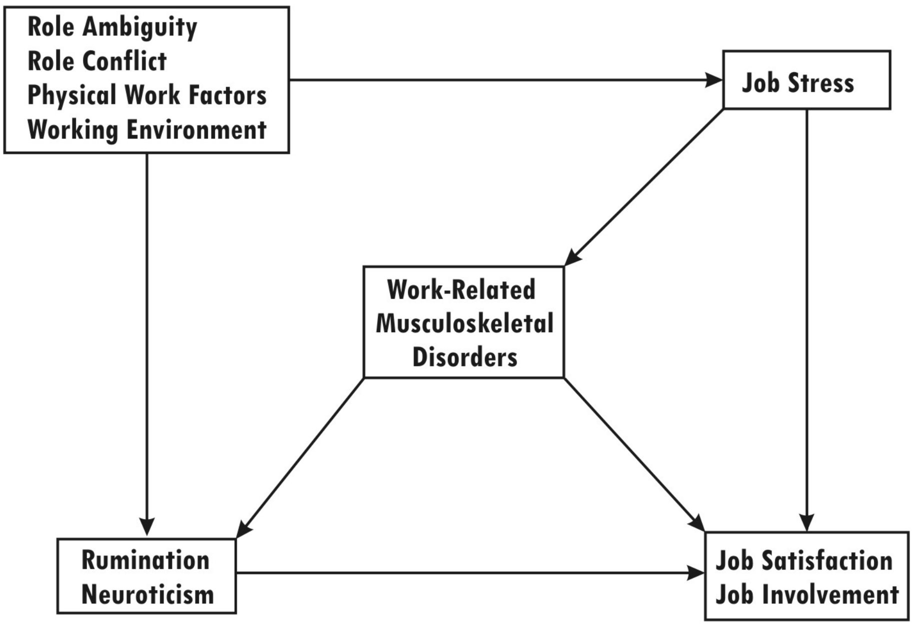

Fig 5.1: Subsystems Represented by Musculoskeletal Disorder –Job Stress System

Table 5.1: Model Boundary Chart for Key Variables in the System

Endogenous	Exogenous
Role ambiguity	Physical work factors
Role conflict	Working environment
Neuroticism	Supervisor's performance
Rumination	
Job Satisfaction	
Job Stress	
Musculoskeletal disorders	
Absenteeism	

To gain a systemic understanding of the problem situation, a reference mode behaviour chart was initially developed for the musculoskeletal disorder – job stress system being modeled. This chart shows the historical development of the problem over time. The reference mode behaviour developed for the musculoskeletal disorder – job stress system shown in Figure 5.2.

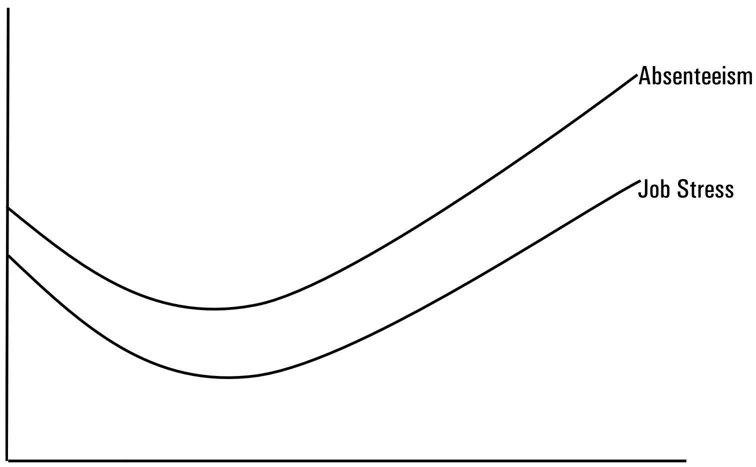

Figure 5.2: Problem Reference Mode for Musculoskeletal Disorder – Job Stress System

In this study, a reference mode behaviour chart was drawn to capture the expected trend of the two key variables related to the problem situation. These two key variables selected are absenteeism which is taken as a measure of work-related musculoskeletal disorders, and job stress. Figure 5.2 presents this behaviour showing an increasing trend of absenteeism which is taken as a measure of work-related musculoskeletal disorders, and job stress.

5.3 Identifying Causal Relations from Literature and the Set Hypotheses

A causal loop diagram (CLD) is the initial step towards the development of quantitative simulation models that can be tested and evaluated for various policies. Presently, a causal loop diagram is developed to explore the influence of job stress and its related factors on musculoskeletal disorders in Indian chemical process industries. The model considers the inducing of job stress by role ambiguity, role conflict, physical work factors, working environment, neuroticism and rumination. The model also captures the effect of job stress on absenteeism, musculoskeletal disorders, rumination, anxiety, job satisfaction and job involvement.

Literature is a source of published outcomes of various research works undertaken all over the world. Causality can be inferred based on the published findings which are already accepted by the scientific community (Menon and Mahanty, 2012). In this section, different existing causal relations in the form of interconnections among the entities in the musculoskeletal disorder – job stress system are identified utilizing the available literature on the system and the insights obtained from the previous confirmatory factor analysis.

5.3.1 Effect of Supervisor's Performance on Role Ambiguity and Role Conflict

In any organization supervisor is to initiate structure which means to provide hints on how to be more effective and efficient. The worker understands more on what is expected and the goals become clearer thereby reducing role ambiguity. On the other side, if the supervisor generates too much structure, it can lead to an uncontrollable situation which elicits role conflict, hostility and rebellion from the workers (Levine et al., 1985).

5.3.2 Effect of Role Ambiguity and Role Conflict on Job Stress and Musculoskeletal Disorders

Role ambiguity and role conflict induces neuroticism which in turn leads to rumination. Moreover, neuroticism as well as rumination leads to job induced anxiety. The anxiety out of the job results in job stress which finally leads to musculoskeletal disorders. Job anxiety also results in a reduced satisfaction out of the job. Decreased job satisfaction reduces the worker's involvement on the Job (Levine et al., 1985). Low levels of worker job involvement alleviate the worker job stress and thus the workplace related musculoskeletal disorders.

5.3.3 Effect of Musculoskeletal Disorders on Job Security and Job Induced Anxiety

The workplace related musculoskeletal disorders forces the worker to take leave from job and thus absenteeism results. Increased worker absenteeism proves to be a threat to the job and thus affects worker's job security negatively. Low levels of job security triggers rumination in workers thereby inducing job related anxiety. Finally this leads to job stress in workers.

The low levels of job security reduce job satisfaction in workers thereby reducing their involvement in the job. Less involvement in job reduces job stress in workers which in turn reduces work-related musculoskeletal disorders and the resulting worker absenteeism. Moreover, increased worker absenteeism due to work-related musculoskeletal disorders results in worker's less involvement in job. The low levels of job involvement by the worker reduce job stress and thus the musculoskeletal disorders and worker absenteeism.

5.3.4 Effect of Physical Work Factors and Working Environment on Musculoskeletal Disorders

The physical work factors and work environment is to influence the job stress in workers. The physical work factors like using keyboard and sitting or standing for a long time negatively affects job stress. Similarly poor working environment like low lighting, high noise level and high temperature at the work site will negatively influence worker's job stress. Hence, the poor physical work factors and working environment increases the job stress further leading to work-related musculoskeletal disorders.

5.4 Development of Causal Loop Diagram

The causal relations identified through the literature were transformed to an adjacency matrix, a method for developing causal loop diagrams from literature (Ali and Ramaswamy, 1993; Camara, 1991). The causal inferences identified are integrated into a matrix to facilitate the selection of variables and polarized relationships. This adjacency matrix is finally translated into the causal loop diagram. The causal relations in an adjacency matrix are read from the row to column direction, i.e. a value in the cell 'X_{ij}' denotes that the variable in the 'i^{th}' row causes the variable in the 'j^{th}' column. In adjacency matrix, +1 denotes that the causing indicator is having a positive impact on the effecting indicator, -1 denotes a negative impact and 0 denotes that there is no cause-effect relationship.

5.4.1 Adjacency Matrix for the Effect of Supervisor's Performance on Role Ambiguity and Role Conflict

The causal effects identified in section 5.3.1 are integrated to the adjacency matrix for the effect of supervisor's performance on role ambiguity and role conflict and is given in Table 5.2. The abbreviations given in the adjacency matrix are included in the developed causal loop diagrams.

Table 5.2: Adjacency Matrix for the Effect of Supervisor's Performance on Role Ambiguity and Role Conflict

System variables	SP	ST	RA	RC
SP	-	-1	0	0
ST	0	-	-1	+1
RA	0	0	-	0
RC	0	0	0	-

The adjacency matrix developed for the effect of supervisor's performance on role ambiguity and role conflict is translated to causal links and is depicted in Figure 5.3.

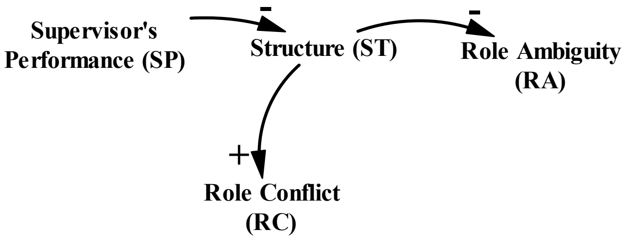

Figure 5.3: The Initiation of Structure by Supervisor's Performance and its Effect on Role Ambiguity and Role Conflict

5.4.2 Adjacency Matrix for the Effect of Role Ambiguity and Role Conflict on Job Stress and Musculoskeletal Disorders

The causal effects identified in sections 5.3.2 are integrated to the adjacency matrix for the effect of role ambiguity and role conflict on job stress and musculoskeletal disorders and is given in Table 5.3. The corresponding causal links are shown in Figure 5.4. The complete job stress – musculoskeletal disorders – job anxiety interaction (B1) is given in the causal loop model shown in Figure 5.5 and in the complete causal loop model depicted Figure 5.7.

Table 5.3: Adjacency Matrix for the Effect of Role Ambiguity and Role Conflict on Job Stress and Musculoskeletal Disorders

System variables	ST	RA	RC	NE	RU	JA	JST	JI	JS	MSD
ST	-	-1	+1	0	0	0	0	0	0	0
RA	0	-	0	+1	0	0	0	0	0	0
RC	0	0	-	+1	0	0	0	0	0	0
NE	0	0	0	-	+1	+1	0	0	0	0
RU	0	0	0	0	-	+1	0	0	0	0
JA	0	0	0	0	0	-	-1	0	+1	0
JST	0	0	0	0	0	0	-	+1	0	0
JI	0	0	0	0	0	0	0	-	+1	0
JS	0	0	0	0	0	0	0	0	-	+1
MSD	0	0	0	0	0	0	0	0	0	-

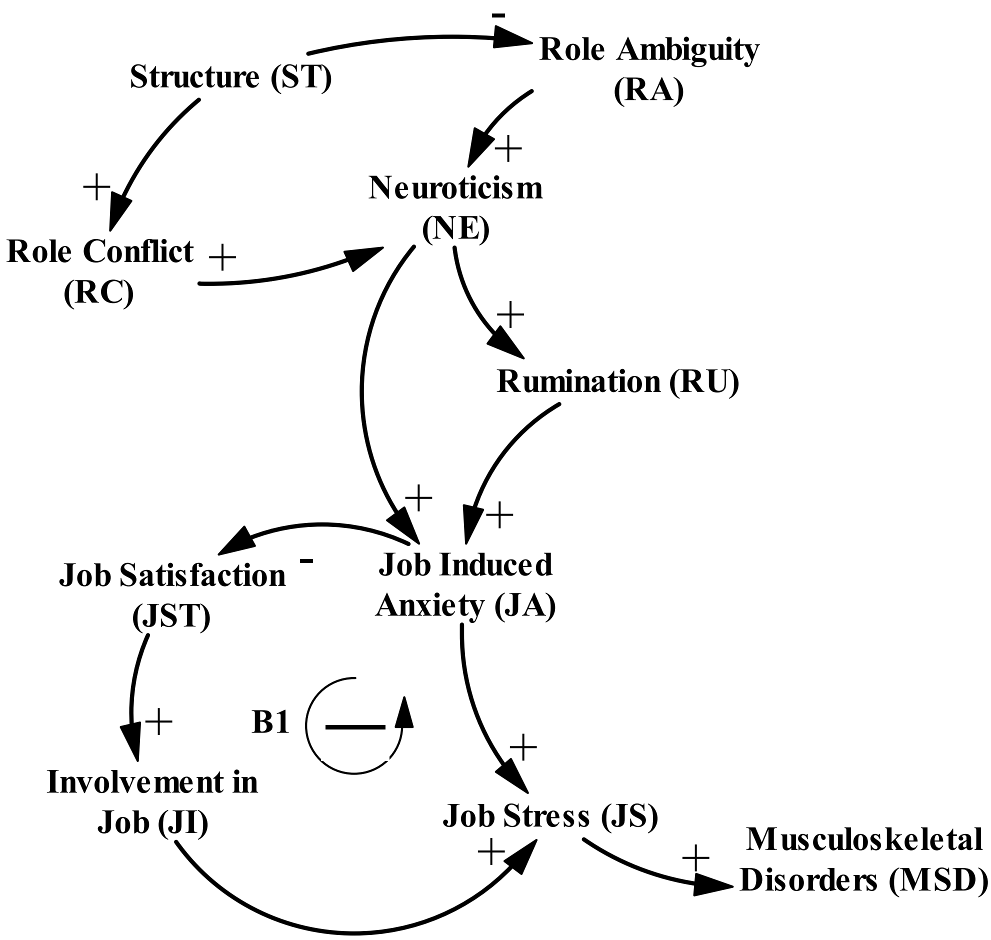

Figure 5.4: The Effect of Role Ambiguity and Role Conflict on Job Stress and Musculoskeletal Disorders and Job Stress – Musculoskeletal Disorders – Job Anxiety Interaction Loop (B1)

5.4.3 Adjacency Matrix for the Effect of Musculoskeletal Disorders on Job Security and Job Induced Anxiety

The adjacency matrix for the effect of musculoskeletal disorders on job induced anxiety is given in Table 5.4.

Table 5.4: Adjacency Matrix for the Effect of Musculoskeletal Disorders on Job Security and Job Induced Anxiety

System variables	AB	JSE	RU	JA	JST	JI	JS	MSD
AB	-	-1	0	0	0	-1	0	0
JSE	0	-	-1	0	+1	0	0	0
RU	0	0	-	+1	0	0	0	0
JA	0	0	0	-	-1	0	+1	0
JST	0	0	0	0	-	+1	0	0
JI	0	0	0	0	0	-	+1	0
JS	0	0	0	0	0	0	-	+1
MSD	+1	0	0	0	0	0	0	-

The adjacency matrix developed for the effect of musculoskeletal disorders on job security and job induced anxiety is translated to form the job stress – musculoskeletal disorders – job security interaction loop (R1), job stress – musculoskeletal disorders – job involvement interaction loop (B2), and musculoskeletal disorders – job security – job satisfaction interaction loop (B3) which are depicted in Figure 5.5.

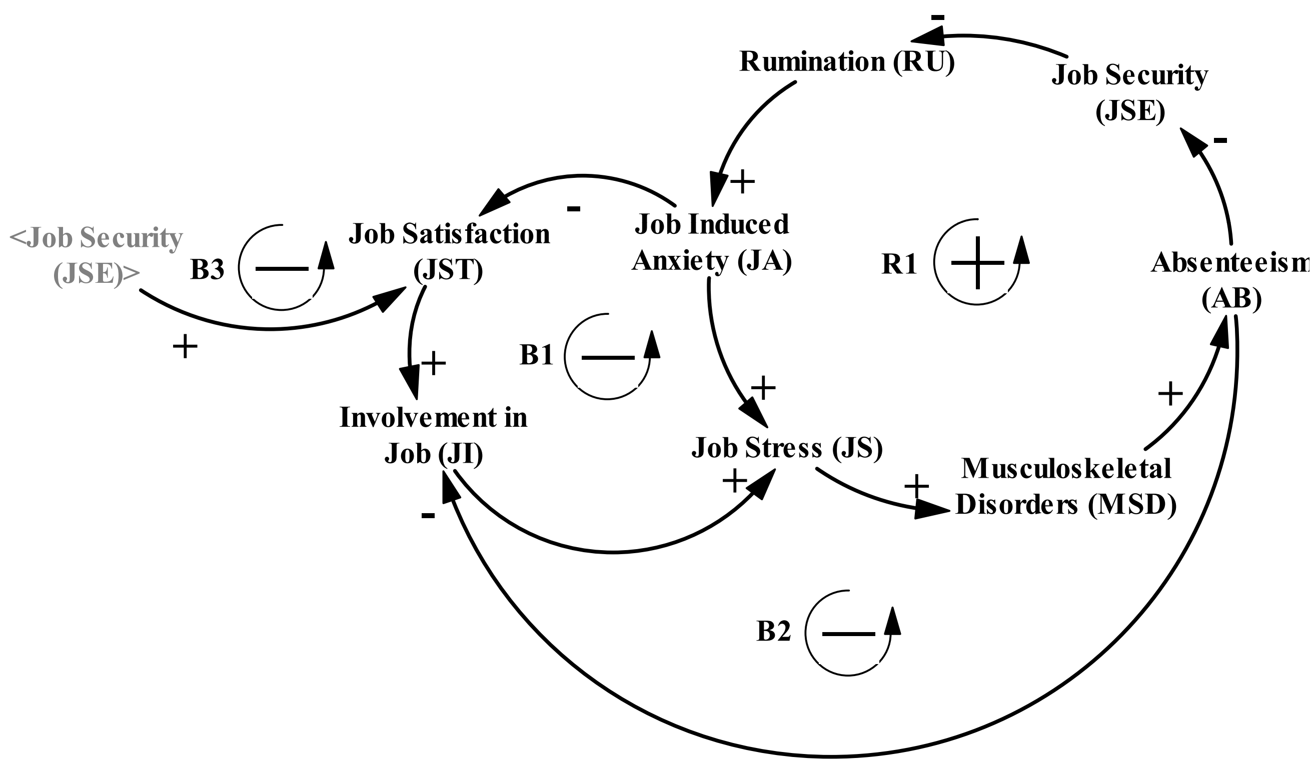

Figure 5.5: Job Stress – Musculoskeletal Disorders – Job Security Interaction Loop (R1), Job Stress – Musculoskeletal Disorders – Job Anxiety Interaction Loop (B1), Job Stress – Musculoskeletal Disorders – Job Involvement Interaction Loop (B2), Musculoskeletal Disorders – Job Security – Job Satisfaction Interaction Loop (B3)

5.4.4 Adjacency Matrix for the Effect of Physical Work Factors and Working Environment on Musculoskeletal Disorders

The causal effects identified in sections 5.3.4 is integrated to the adjacency matrix for the effect of physical work factors and working environment on musculoskeletal disorders and is given in Table 5.5. This matrix is translated to the corresponding causal loops which are shown in Figure 5.6.

Table 5.5: Adjacency Matrix for the Effect of Physical Work Factors and Working Environment on Musculoskeletal Disorders

System variables	PWF	WE	JS	MSD
PWF	-	0	+1	0
WE	0	-	+1	0
JS	0	0	-	+1
MSD	0	0	0	-

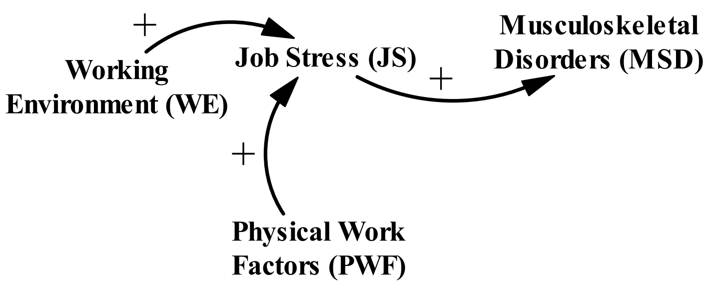

Figure 5.6: Effect of Physical Work Factors and Working Environment on Musculoskeletal Disorders

The complete feedback loop or the causal loop model developed is presented in Figure 5.7. In the present causal model, only the main loops are labeled to avoid confusion in interpreting the model. Table 5.6 gives the detailed description of the variables used in the causal model. Table 5.7

gives the details on main labeled loops, loop polarity, loop name and loop components.

The causal model presented in Figure 5.7 captures the effect of job stress and its related variables of role ambiguity, role conflict, physical work factors and working environment on the work-related musculoskeletal disorders, the understanding of which are important in making policies towards mitigating the job stress levels and those job stress related factors (revealed in the previous structural modeling effort) in chemical process industries in India.

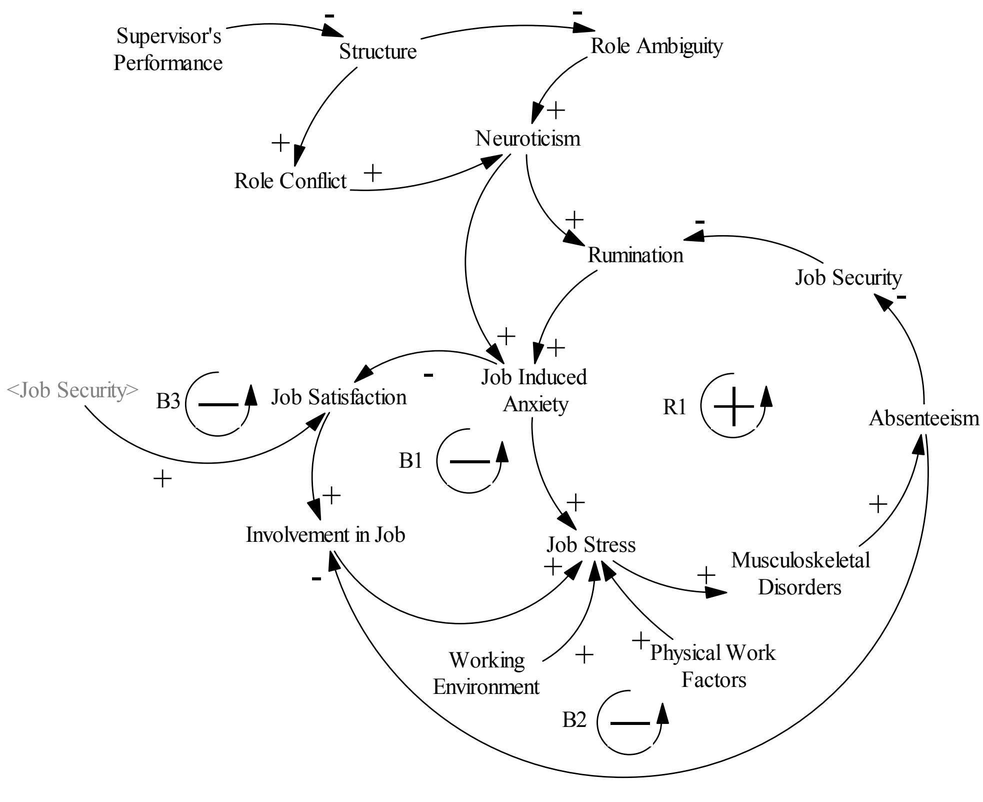

Figure 5.7: Complete Causal Model for the Work-Related Musculoskeletal Disorder – Job Stress System

Table 5.6: Description of the Variables used in the Causal Loop Model

Variable	Description	Endogenous/ Exogenous	Loop to which the variable belongs
Supervisor's performance	Supervisor's sensitivity to performance.	Exogenous	No
Structure	Hierarchy of authority in the process industry.	Endogenous	No
Role ambiguity	A lack of clarity about the expected behaviour from a job or position experienced by a worker.	Endogenous	No
Role conflict	Conflict among the roles corresponding to two or more statuses experienced by a worker.	Endogenous	No
Neuroticism	An enduring tendency of the worker to experience negative emotional states such as anxiety, anger, guilt and depression.	Endogenous	No
Rumination	A mode of worker's response to distress that involves passively focusing his attention on symptoms of distress without taking action.	Endogenous	R1, B1
Job induced anxiety	The extent that a worker experiences the symptoms of anxiety resulting from his work situation.	Endogenous	R1, B1
Job stress	The harmful physical and emotional responses that occur when job requirements do not match the worker's capabilities, resources and needs.	Endogenous	R1, B1, B2, B3
Musculoskeletal disorders	Denotes health problems of muscles, tendons, skeleton, cartilage, ligaments and nerves which are induced by work and circumstances of its performance.	Endogenous	R1, B1, B2, B3
Absenteeism	Referred to as the failure of employees to report for work when they are scheduled to work.	Endogenous	R1, B1, B2, B3
Job security	Job Security is an assurance that an individual will keep his or her job without the risk of becoming unemployed.	Endogenous	R1, B1, B3
Job satisfaction	Contentment (or lack of it) arising out of interplay of worker's positive and negative feelings towards his work.	Endogenous	B1, B3
Involvement in job	The degree to which an employee is engaged in and enthusiastic about performing their work.	Endogenous	B1, B2, B3
Physical work factors	Use of tangibles like keyboard, chair, stool etc. by the worker while performing his job.	Exogenous	No
Working environment	The surrounding environment which involves lighting, temperature, noise etc. in which the worker performs his job.	Exogenous	No

Table 5.7: Details of causal Model on Feedback Loops, Loop Polarity, Loop Name and Loop Components

Feedback loop ID	Balancing (-) or reinforcing (+) loop	Feedback loop name	Feedback loop components
R1	Reinforcing	Job Stress – musculoskeletal disorders – job security interaction loop	Job stress, Musculoskeletal disorders, Absenteeism, Job security, Rumination, Job induced anxiety
B1	Balancing	Job stress – musculoskeletal disorders – job anxiety interaction loop	Job stress, Musculoskeletal disorders, Absenteeism, Job security, Rumination, Job induced anxiety, Job satisfaction, Involvement in job
B2	Balancing	Job stress – musculoskeletal disorders – job involvement interaction loop	Absenteeism, Involvement in job, Job stress, Musculoskeletal disorders
B3	Balancing	Musculoskeletal disorders – job security – job satisfaction interaction loop	Job stress, Musculoskeletal disorders, Absenteeism, Job security, Job satisfaction, Involvement in job

5.5 Discussions on the Developed Feedback Loop Diagram

The four feedback (causal) loops namely job Stress – musculoskeletal disorders – job security interaction loop (R1), job stress – musculoskeletal disorders – job anxiety interaction loop (B1), job stress – musculoskeletal disorders – job involvement interaction loop (B2) and musculoskeletal disorders – job security – job satisfaction interaction loop (B3) were combined to form the complete feedback loop model for the work-related musculoskeletal disorders – job stress system in chemical process industries in India.

The complexity in the organizational structure results in role ambiguity and role conflict thereby triggering neuroticism and rumination.

This leads to job induced anxiety which in turn induces job stress. High levels of job stress in workers leads to work-related musculoskeletal disorders forcing the workers to take leave from job. Increased absenteeism affects their job security and rumination results which trigger anxiety and the vicious loop continues. Thus this job Stress – musculoskeletal disorders – job security interaction loop (R1) is reinforcing in nature. Job induced anxiety in workers reduces worker's job satisfaction and thus their involvement in job thereby reducing the job stress. This forms the balancing loop named job stress – musculoskeletal disorders – job anxiety interaction loop (B1). Worker absenteeism in turn also affects workers involvement in job and which give rise to the job stress – musculoskeletal disorders – job involvement interaction loop (B2) of balancing nature. A low level of job security affects worker's job satisfaction negatively which causes a reduction in his involvement in job. This will in turn reduce the job stress in workers. This loop is a balancing loop and is the musculoskeletal disorders – job security – job satisfaction interaction loop (B3).

5.6 Conclusions

In this chapter, a conceptual modeling framework is developed to capture the feedback loops existing in the work-related musculoskeletal disorders – job stress system in chemical process industries in India. The causal relationships in the feedback loop model were based on the insights from the existing literature, knowledge of the real system and on the outcomes of the structural modeling efforts. There are 20 cause-effect relationships in the developed feedback loop model. The identified feedback loops were translated to a causal loop diagram using the adjacency matrix method.

The feedback loop analysis has helped in understanding the effect of job stress and its factors on work-related musculoskeletal disorders in chemical process industries in India. The developed causal loop model captures the dynamic interactions between the variables in the system considered which include job stress, neuroticism, rumination, physical work factors, working environment, work-related musculoskeletal disorders, job anxiety and job involvement.

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Chapter 6

DYNAMIC MODELING FOR THE INFLUENCE OF JOB STRESS ON WORK-RELATED MUSCULOSKELETAL DISORDERS IN CHEMICAL PROCESS INDUSTRIES IN INDIA

Contents

6.1Introduction

A causal loop diagram is used to understand the system considered and the interrelations between the system variables. But causal loop diagrams have several limitations, one of which is their inability to capture the stock and flow structure of systems. Thus, the causal loop diagrams along with the stock and flow diagram completes the means for communicating the system structure (Morecroft, 1982; Richardson, 1985).

The variable of job stress is influenced by various factors like role ambiguity, role conflict, neuroticism and rumination, all of which in turn induces and influence the work-related musculoskeletal disorders in chemical process industries in India. The dynamic interaction between these systemic variables can be effectively captured utilizing the system dynamics modeling.

This chapter presents the development of a system dynamics model to assess the influence of job stress and its associated variables on inducing the work-related musculoskeletal disorders in chemical process industries in the country. To achieve this aim, the feedback loops developed are translated into a stock and flow diagram to quantify the effect of job stress on musculoskeletal disorders. The model developed considers variables which include the job stress, role conflict, role ambiguity, neuroticism, rumination, job satisfaction, job anxiety and musculoskeletal disorders. The chapter also includes the policy analysis.

6.2 System Dynamics Modeling – The Basic Structure

System dynamics model developed in this section is through the identification of various constants and levels, rate and auxiliary variables in the work-related musculoskeletal disorder – job stress system. The model is developed iteratively ensuring that the model developed is in accordance with the causal relationships that exist between the entities in the system.

The system dynamics model is built to capture the following five important dynamics namely (a) supervisor's performance and workers role dynamics, (b) job satisfaction and job involvement dynamics, (c) job stress dynamics, and (d) work-related musculoskeletal disorders – job stress dynamics.

6.2.1 Supervisor's Performance and Worker's Role Dynamics

The stock and flow model for the worker role dynamics is shown in Figure 6.1. The supervisor's performance in the shop floor generates structure and if it aids the worker in understanding what is expected of him reduces his role ambiguity. On the other way round, if the supervisor generates too much structure thereby confusing the workers can induce role conflict among them (Levine et al., 1985). This in turn can lead to neuroticism which results in rumination and job induced anxiety. Moreover rumination also directly contributes to the job induced anxiety.

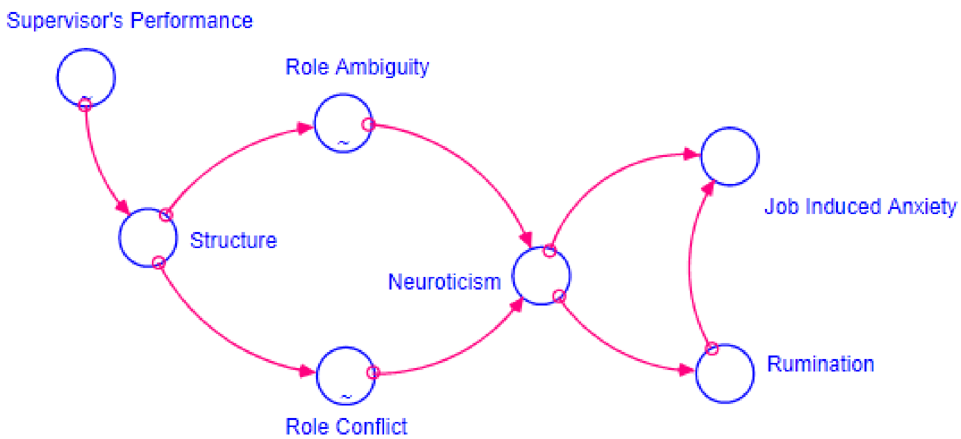

Figure 6.1: Supervisor's Performance and Worker's Role Dynamics

6.2.2 Job Satisfaction and Job Involvement Dynamics

The stock and flow model for the four-wheeler ownership dynamics is shown in Figure 6.2. The job induced anxiety influence job satisfaction negatively. The job satisfaction in turn positively influences the worker's involvement in the job. The job involvement of the worker again positively influences the worker's job stress. This means more the worker's job involvement more is his job stress and vice versa. The job induced anxiety also influences the job stress in a negative manner.

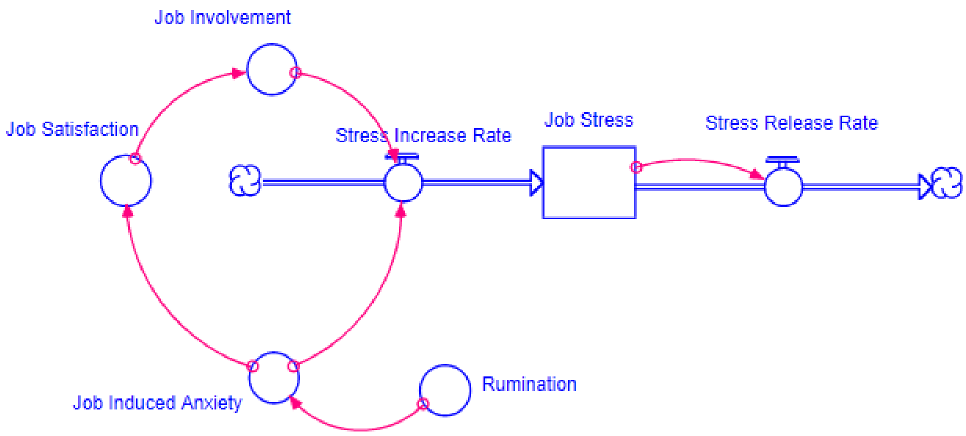

Figure 6.2: Job Satisfaction and Job Involvement Dynamics

6.2.3 Job Stress Dynamics

The job involvement of workers as well as the job induced anxiety in workers is to positively influence the worker's job stress. Similarly, poor physical work factors and poor working environment, as explained in section 5.3.4 in the previous chapter, is to increase the job stress in workers considerably.

The stock and flow model for the job stress dynamics is shown in Figure 6.3. The job stress factor is represented as a level variable. This job stress level variable is increased by stress increase rate and is depleted by stress release rate. The stress increase rate and stress release rate are both rate variables in the model.

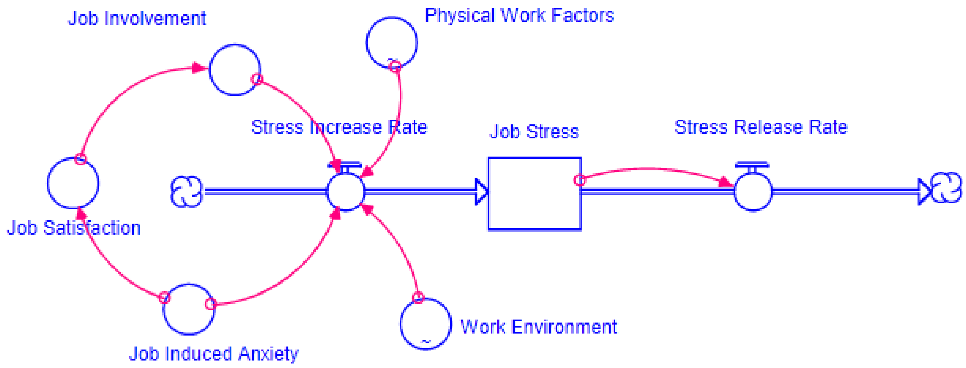

Figure 6.3: Job Stress Dynamics

Thus the "job stress" in the stock and flow model is modeled as:

Job Stress (t) = Job Stress (t - dt) + (Stress Increase Rate – Stress Release Rate) * dt

6.2.4 Work-RelatedMusculoskeletal Disorders – Job Stress Dynamics

The stock and flow diagram for the work-related musculoskeletal disorders – job stress dynamics is depicted in Figure 6.4. An increase in job stress results in work-related musculoskeletal disorders which in turn lead to absenteeism of workers in chemical process industries. In the present modeling venture, musculoskeletal disorders are indirectly measured in terms of absenteeism of the workers as below.

Absenteeism = Job Stress*WRMSD Fraction

where "WRMSD Fraction" is the fraction of days taken as leave due to musculoskeletal disorders in workers in chemical process industries.

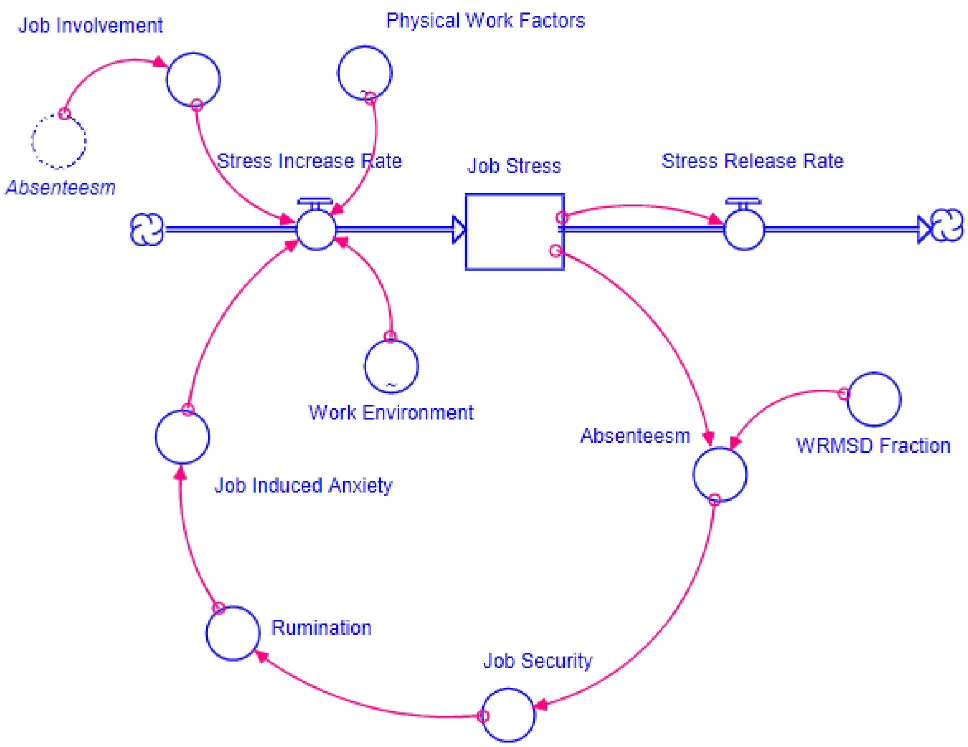

Figure 6.4: Work-RelatedMusculoskeletal Disorders – Job Stress Dynamics

Increase in absenteeism affects job security of the workers as more the days absent, less the job security is. The low levels of job security increases rumination and job induced anxiety leading to an increase in job stress. The absenteeism also considerably influences the extent of worker's involvement in job negatively. This also in turns adds up to the job stress in workers. Thus this vicious cycle continues.

The completestock and flow diagram for the work-related musculoskeletal disorder – job stress system in chemical process industries in India is depicted in Figure 6.5.

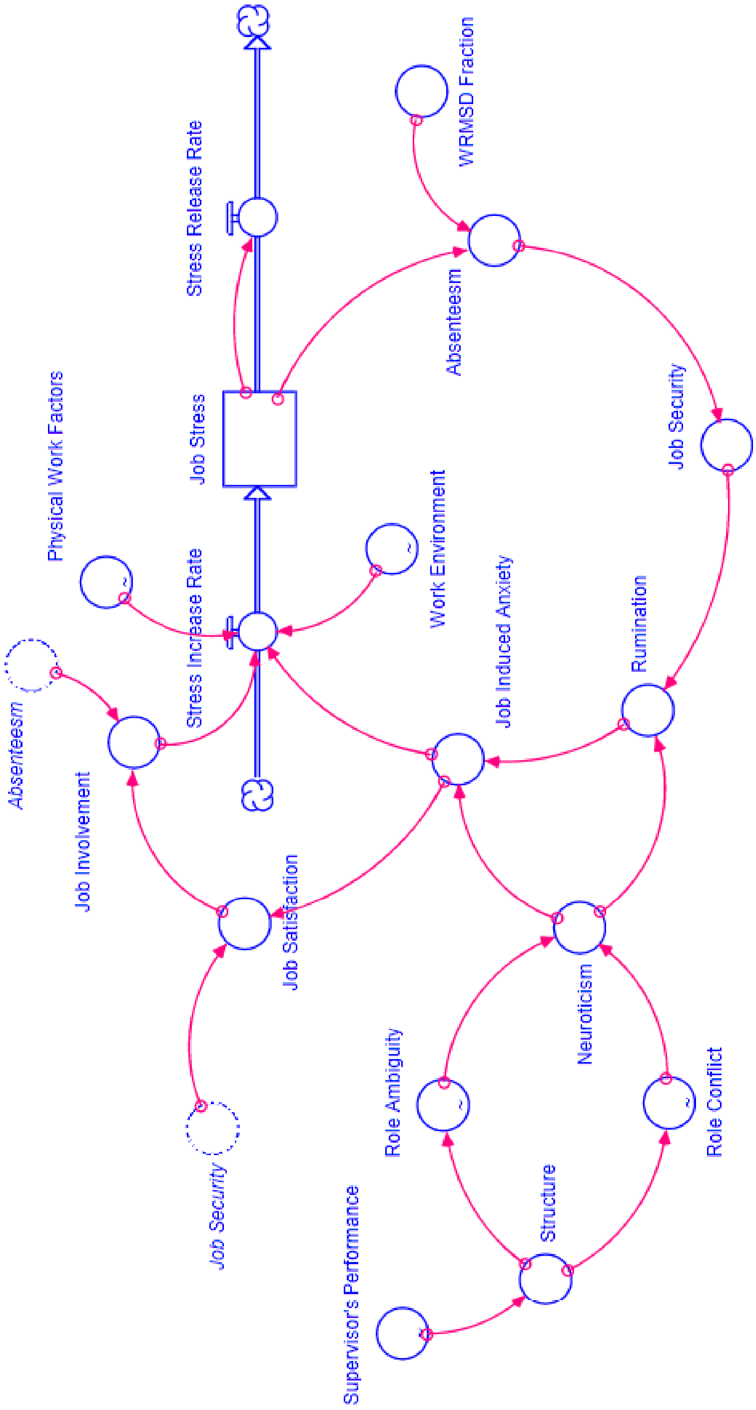

Figure 6.5: Complete Stock and Flow Diagram for the Work-RelatedMusculoskeletal Disorder – Job Stress System

6.3 Validation of the System Dynamics Model

Simulation models based on system dynamics methodology are becoming increasingly popular in the analysis of systemic behaviour over time. The usefulness of these models rests on their ability to link observable patterns of behaviour of a system to micro-level structures (Qudrat-Ullah and Seong, 2010). This, in turn, is checked through model validation procedures. The primary aim of model validation is to have confidence in the model developed (Mohapatra et al., 1994). Presently two important tests namely boundary adequacy test and comparison to reference modes are conducted to validate the work-related musculoskeletal disorder – job stress system dynamics model. The tests for the system dynamics model validation are described below.

6.3.1 Boundary Adequacy Test

The boundary adequacy test is to check whether the important concepts and structures for addressing the research issues are endogenous to the model (Qudrat-Ullah and Seong, 2010). Table 5.1 in the previous chapter list all the endogenous and exogenous variables considered in the model. Consistent with the purpose of the model developed, all the major system variables like role ambiguity, role conflict, neuroticism, rumination, job satisfaction, job stress, musculoskeletal disorders and absenteeism are endogenously generated.

6.3.2 Comparison to Reference Modes

Reference mode behaviour is developed to answer whether the model reproduces the problem behaviour adequately for the purpose (Sterman, 2000). The reference mode is developed in Chapter 5. The reference mode behaviour depicted in Figure 5.2 (chapter 5) and model generated behaviour for job stress and absenteeism in Figure 6.6 is found to have similar profile. This in turn shows that the expected behaviour for the system variables of job stress and absenteeism is roughly matching with that of the model generated behaviour thereby validating the model developed.

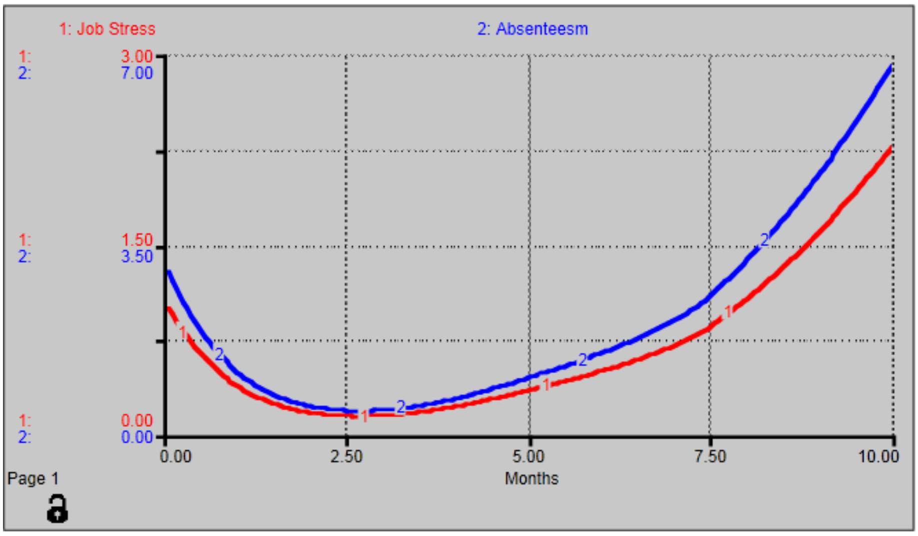

Figure 6.6: Simulated Behaviour for Job Stress and Absenteeism Variables

6.4 Dynamics of Work-RelatedMusculoskeletal Disorders – Job StressSystem

In order to obtain the dynamics of job stress and its associated variables influence on work-related musculoskeletal disorders in workers of chemical process industries in India, a stock and flow diagram was developed using STELLA 5.0 software. The stock and flow diagram has considered all the causal relationships between all the exogenous and endogenous variables considered in the study (Figure 6.5). The model is based on the data collected from the governmental and non-governmental chemical process industries in the state of Kerala, India. Model simulation is done for a time horizon of 10 months. The dynamics of work-related musculoskeletal disorders – job stress system are discussed in the sub-sections that follow.

6.4.1 Base Run Scenario

Initially the base run of the system dynamics model was carried out. Figure 6.6 shows the base run behaviour of job stress and absenteeism due to work-related musculoskeletal disorders under the influence of job involvement. As evidenced from the Figure 6.7, initially when the worker job involvement is less, the job stress and absenteeism showed a decreasing behaviour. As the worker involvement started to increase after 1.5 months, the job stress and absenteeism also started to increase. This is in line with the results of Levin et al. (1985).

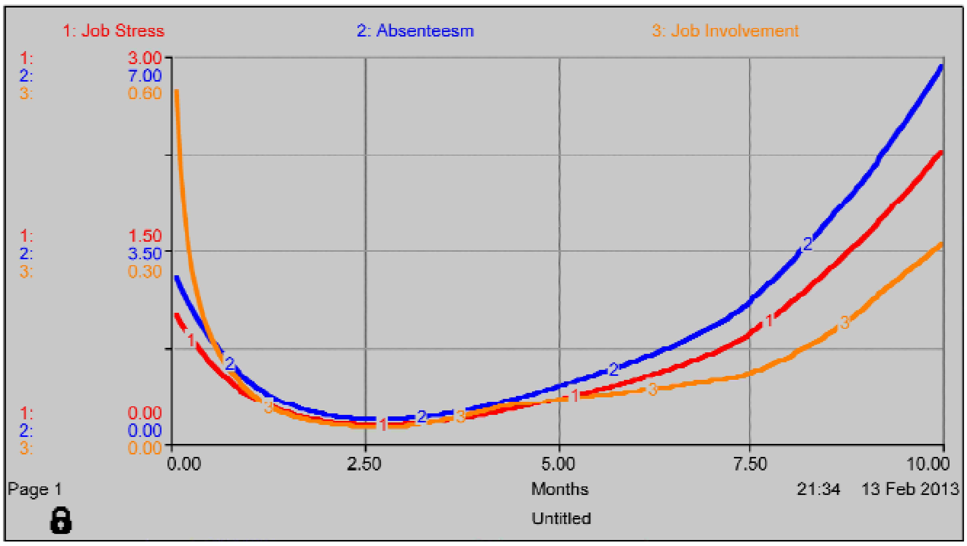

Figure 6.7: Job Involvement, Job Stress and Absenteeism for Base Run Scenario

As evidenced from the Figure 6.7, initially when the worker job involvement is less, the job stress and absenteeism showed a decreasing behaviour. As the worker involvement started to increase after 1.5 months, the job stress and absenteeism also started to increase. This is in line with the results of Levin et al. (1985).

Figure 6.8 shows the behaviour of job stress and absenteeism under the influence of poor physical work factors and poor work environment.

As the poor physical work factors and poor work environment increases, the job stress is found to build up which resulted in increasing absenteeism due to work-related musculoskeletal disorders as evident from the base run simulation results (Figure 6.8).

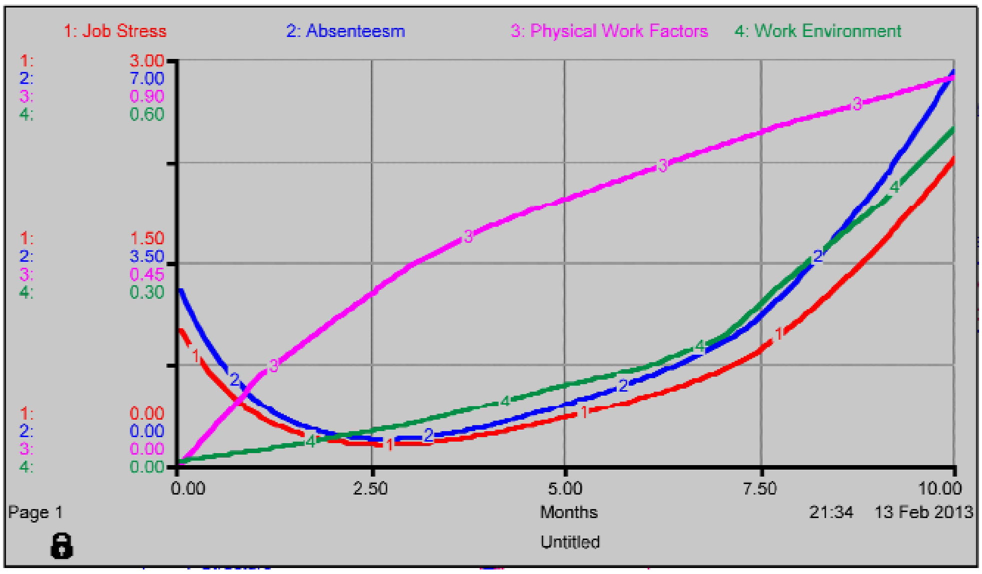

Figure 6.8: Job Stress, Absenteeism, Physical Work Factors & Work Environment for Base Run Scenario

Moreover, from Figure 6.9 below, it is also evident that the increase in role ambiguity and role conflict leads to an increase in job stress levels.

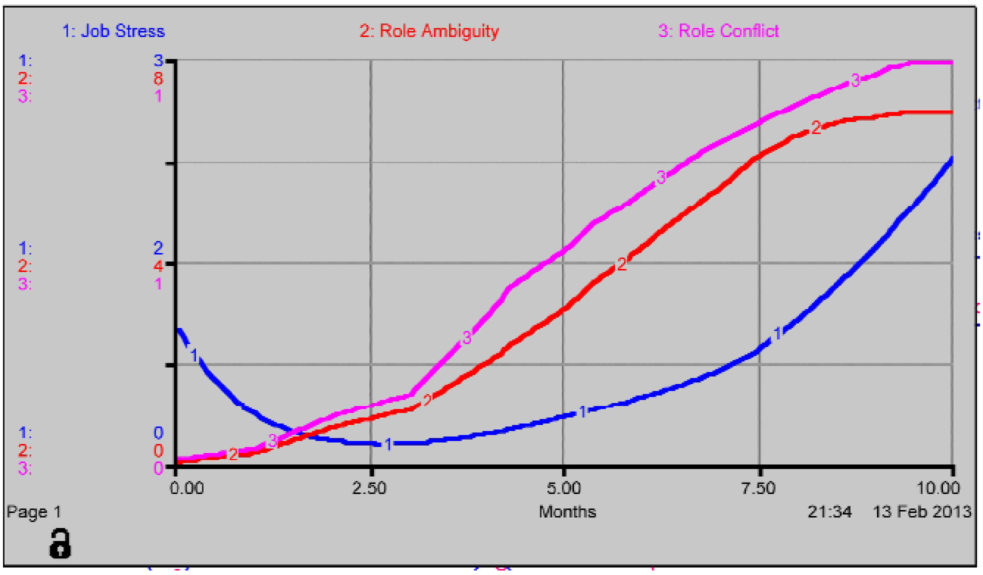

Figure 6.9: Job Stress, Role Ambiguity and Role Conflict for Base Run Scenario

6.5 Policy Analysis

As evident from the base run simulation results, the job stress and its associated variables is to considerably influence the work-related musculoskeletal disorders in chemical process industries in India. To mitigate the job stress induced musculoskeletal disorders in chemical process industries three policy interventions were adopted which are given below:

1. Policy 1: Improving the physical work factors.
2. Policy 2: Improving the work environment.

3. Policy 3: Combined policy of improving the physical work factors and the work environment.

The aim is to create policy synergy that would bring about the best possible scenario in terms of mitigation of work-related musculoskeletal disorders measured in terms of absenteeism. This section investigates the above listed three policies towards attaining this aim.

6.5.1 Policy 1: Improving the Physical Work Factors Policy

The policy-1 of improving the physical work factors towards mitigating the work-related musculoskeletal disorders in chemical process industries in India was simulated and the results are depicted in Figure 6.10.

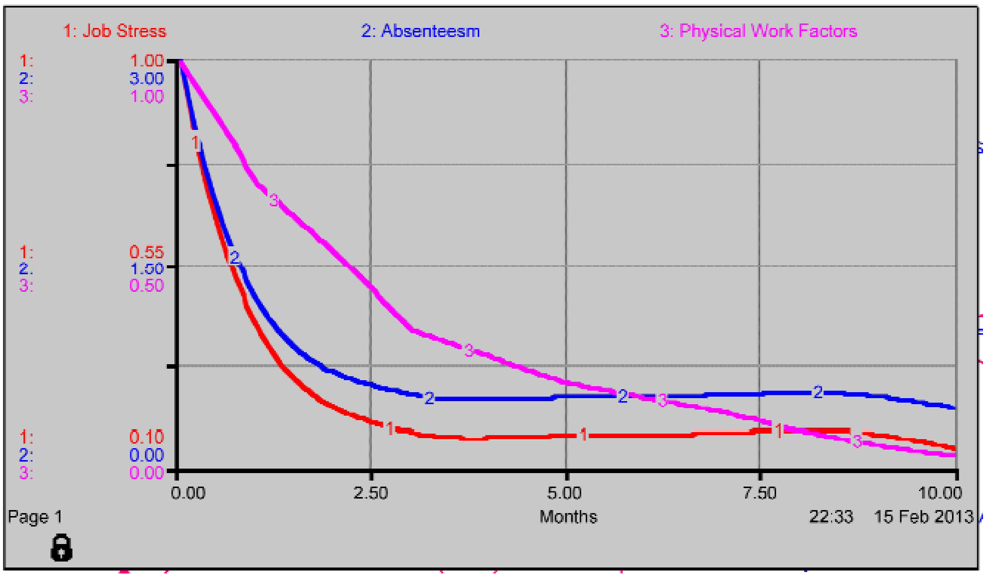

Figure 6.10: Job Stress and Absenteeism for Improved Physical Work Factor Policy

From the Figure 6.10, it is evidenced that the improvement in physical work factors has reduced the level of job stress and the resulting musculoskeletal disorders in workers as seen from the reducing absenteeism of the workers.

6.5.2 Policy 2: Improving the Work Environment Policy

The policy-2 of improving the work environment towards mitigating the work-related musculoskeletal disorders in chemical process industries in India was simulated and the results are depicted in Figure 6.11.

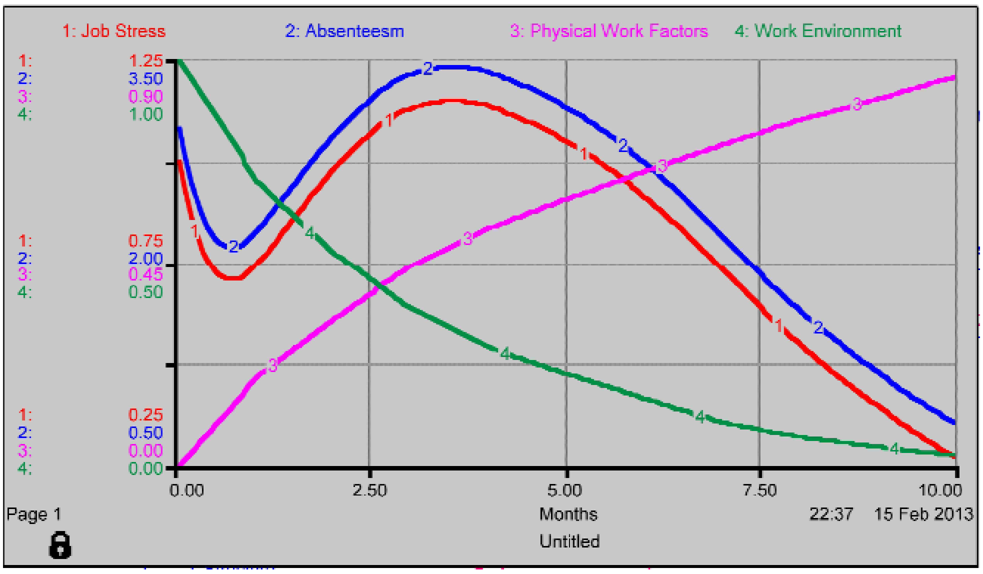

Figure 6.11: Job Stress and Absenteeism for Improved Work Environment Policy

As evidenced from the Figure 6.11, the improvement in work environment in chemical process industries has reduced the level of job stress leading to a drop in worker absenteeism. The fall in the number of days absent in turn indicates the decrease in work-related musculoskeletal disorders in the workers.

6.5.3 Policy 3: Combined Policy of Improving the Physical Work Factors and theWork Environment

A combination of policy-1 and 2, i.e. of improved physical work factors and improved work environment, was applied as policy-3 and simulation was rerun. The system dynamics simulation result for the combined policy is shown in Figure 6.12.

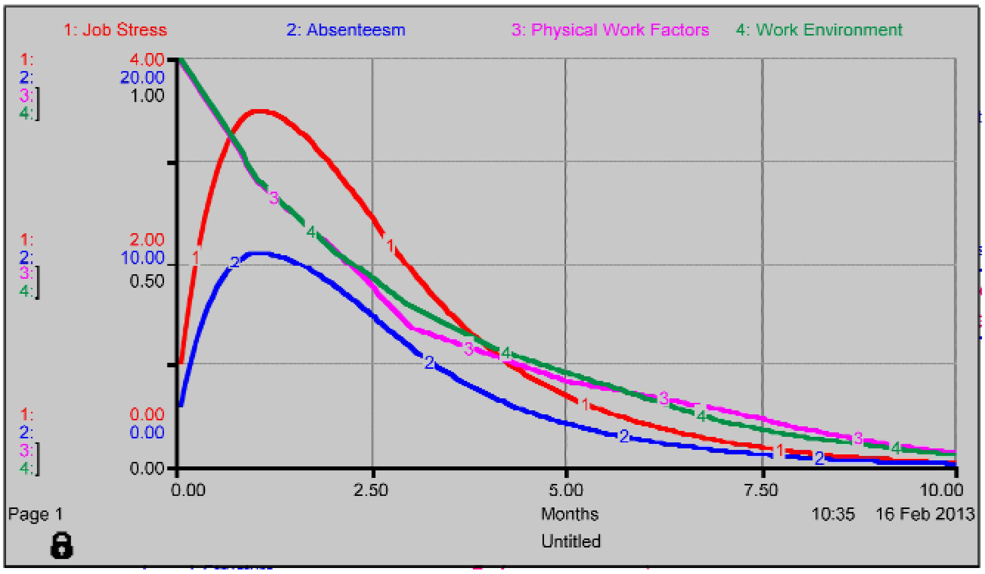

Figure 6.12: Job Stress and Absenteeism for Combined Policy

The combined policy of improved physical work factors and work environment has served its intended purpose of mitigating work-related musculoskeletal disorders in chemical process industries in India. Initially the job stress and absenteeism had an overshoot for a period of one month. This is due to the short delay for the combined policy to take effect. After onemonth the job stress and musculoskeletal disorders started to gradually decline over time.

6.6 Discussion on Policy Run Results

Table 6.1 gives the system dynamics base run and policy run simulation results.

Table 6.1: System Dynamics Base Run and Policy Run Simulation Results

Months	Base Run		Policy-1		Policy-2		Policy-3	
	Job Stress	Absenteeism (Days)	Job Stress	Absenteeism (Days)	Job Stress	Absenteeism (Days)	Job Stress	Absenteeism (Days)
1	0.37	1.0	0.41	1.0	0.75	2.0	3.50	10.51
2	0.17	0.5	0.23	0.70	0.99	2.96	2.91	8.73
3	0.15	0.5	0.18	0.50	1.13	3.40	1.90	5.69
4	0.23	0.68	0.17	0.50	1.14	3.41	1.13	3.38
5	0.35	1.0	0.17	0.51	1.05	3.15	0.67	2.02
6	0.51	1.5	0.17	0.52	0.92	2.75	0.40	1.20
7	0.71	2.0	0.18	0.53	0.73	2.20	0.23	0.70
8	1.08	3.0	0.18	0.55	0.55	1.65	0.13	0.38
9	1.61	5.0	0.17	0.52	0.40	1.19	0.06	0.19
10	2.28	7.0	0.14	0.43	0.27	0.81	0.03	0.09

From the simulation run results, when compared to the base run results, it is evident that all the three policies has served its intended purpose of reducing the levels of job stress thereby mitigating the work-related musculoskeletal disorders which is evident through the reduction in absenteeism. Thus all the three policies are feasible towards attaining this aim. It is also found from the simulation results that the best policy towards mitigating job stress and the related musculoskeletal disorders is the policy-3 which is the combined policy of improved physical work factors and improved work environment. It is evident from the values that in the long run the combined policy has outperformed the policy-1 of improving physical work factors and policy-2 of improving work environment. Thus this policy should be adopted in Indian chemical process industries towards reducing the job stress levels thereby mitigating the work-related musculoskeletal disorders in the workers in the long run.

6.7 Conclusions

From the initial system dynamics simulation (base run) results, the following conclusions are made.

1. The job stress in chemical process industries in India is influenced by role ambiguity and role conflict.
2. The job stress in chemical process industries in India is also influenced by physical work factors and work environment.
3. The job stress in turn influences the work-related musculoskeletal disorders, which is measured in terms of worker absenteeism, in chemical process industries in India.

In order to mitigate the work-related musculoskeletal disorders due to job stress and its associated variables in Indian chemical process industries in the long-run, short-term fixes in the structure may not be helpful. Here it requires long-term structural changes to be devised to change the behaviour of the system. With this aim, three different complimentary policies of improving physical work factors (policy-1), improving work environment (policy-2), and a combination of policy-1 and 2 (policy-3) were experimented. The conclusions made out of the policy experimentation results are summarized below.

1. All the three policies of improving physical work factors, improving work environment and the combined policy has served the intended

purpose of reducing the job stress levels thereby mitigating the work-related musculoskeletal disorders in chemical process industries in India.

2. The combined policy outperformed the individual policies of improved physical work factors and improved work environment in mitigating the job stress and the work-related musculoskeletal disorders in the chemical process industries in India in the long run.

As the combined policy (policy-3) performed the best when compared to base run, improving of physical work factors policy (policy-1), and improving of work environment policy (policy-2), this policy is to be adopted in the chemical process industries in India towards lowering the levels of job stress thereby mitigating the musculoskeletal disorders in the workers in the long run.

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Chapter 7

CONCLUSION AND FUTURE SCOPE OF STUDY

Contents

7.1 Introduction

This chapter gives the summary of the work done in the thesis followed by the conclusions of the research work undertaken and the contributions of the research work in the area of work-related musculoskeletal disorders – job stress system. The chapter also gives the scope for future work in the present line of research and finally the conclusion is laid out.

7.2 Summary of Work Done in the Thesis

The research work done in the thesis is summarized below:

1. The present research has considered the issues of increasing work-related musculoskeletal disorders in relation to job stress in chemical process industries in India.
2. A literature survey is carried out on job stress and its related factors on musculoskeletal disorders in India.

3. The study has developed an instrument framework towards measuring job stress utilizing exploratory factor analysis and structural equation modeling.
4. A conceptual modeling framework is developed to capture the feedbacks involved in the system for assessing the influence of job stress and its related factors on work-related musculoskeletal disorders in chemical process industries in India. The causal loop modeling of system dynamics methodology has been utilized for this purpose.
5. The developed feedback loop model is transformed to a stock and flow model to quantify the influence of job stress on work-related musculoskeletal disorders in chemical process industries in India.
6. Different policies are experimented to mitigate the work-related musculoskeletal disorders due to job stress in chemical process industries in India.
7. Conclusions are made on the research work undertaken. The contributions of the research and the future scope of work are discussed.

7.3 Conclusions of the Thesis

The conclusions of the thesis are as follows:

1. The exploratory factor analysis gave an eight factor structure for job stress in chemical process industries in India. This was confirmed through confirmatory factor analysis – a method of structural equations modeling.

2. The confirmatory factor analysis revealed that the variables of role ambiguity, role conflict, physical work factors and work environment are the most influential variables of job stress in chemical process industries in Kerala, India.
3. The system dynamics base run simulation results showed that role ambiguity, role conflict, physical work factors and work environment increase the job stress levels thereby leading to increased worker absenteeism. This in turn is an indication of the increase in work-related musculoskeletal disorders in workers in Indian chemical process industries.
4. The individual policies of improving physical work factors (policy-1) and improving work environment (policy-2) and the combination of these policies (policy-3) has served the intended purpose of reducing the job stress levels thereby mitigating the musculoskeletal disorders among the workers in chemical process industries in the country.
5. The combined policy of improved physical work factors and improved work environment conditions (policy-3) was found to outperform the policy-1 and 2 in mitigating the job stress and it's induced work-related musculoskeletal disorders in chemical process industries in the long run.

7.4 Contributions of the Thesis

The contributions of the thesis are as follows:

1. Literature survey on the job stress induced work-related musculoskeletal disorders in process industry.
2. Framing of a structured questionnaire on the basis of literature, interviews and discussions with the personals in the selected chemical process industries.
3. Developed an instrument framework for measuring workplace job stress in chemical process industries in Kerala, India.
4. Identified the eight factors of role ambiguity, role conflict, physical work factors, working environment, decision latitude, threat of physical harm, social support and additional responsibilities that is to influence job stress in chemical process industries in Kerala, India.
5. Developed a system dynamics model to analyze the influence of job stress and its factors on work-related musculoskeletal disorders in chemical process industries in Kerala, India.
6. Experimented with three policies of improving physical work factors (policy-1), improving work environment (policy-2) and a combination of these policies (policy-3) towards reducing the job stress and the associated musculoskeletal disorders in workers in chemical process industries in the country.
7. Suggested the combined policy of improved physical work factors and work environment (policy-3) towards the mitigation of job stress

and its induced work-related musculoskeletal disorders in chemical process industries in Kerala, India.

7.5 Scope for Further Research

Following are the scope for further research:

1. The research work was carried out in the chemical process industries in Kerala state, India. The utility of the job stress instrument in industries other than process industrieswithin Kerala needs further explorations.
2. The utility of the job stress instrument in chemical process industries as well as other industriesacross the Indian states other than Kerala needs further explorations.

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REFERENCES

1. Ali, S.K. and Ramaswamy, N. (1993), "Statistical methods for improving confidence in system dynamics models – a case study on blood bank inventory management systems",*Proceedings of the International System Dynamics Conference*, Cancun, Mexico, pp. 82-87.

2. Anderson, C. (1976), "Coping behaviours as intervening mechanisms in the inverted-U stress-performance relationship",*Journal of Applied Psychology,*Vol.61, No. 1, pp. 30-34.

3. Bandalos, D.L. (2002), "The effects of item parceling on goodness-of-fit and parameter estimate bias in structural equation modeling",*Structural Equation Modeling*, Vol.9,No.1,pp. 78-102.

4. Barhem, B., Sidin, S.M., Abdullah, I. and Alsagoff, S.K. (2004), "A new model for work stress patterns",*Asian Academy of Management Journal*, Vol.9, No.1, pp. 53-77.

5. Beehr, T.A. and Drexler, J.A. (1986), "Social support, autonomy and hierarchical level as moderators of the role characteristics-outcome relationship", *Journal of Occupational Behaviour*, Vol.7, No. 3, pp. 207-214.

6. Bertha, A. (2011), "Prevalence of upper extremity musculoskeletal disorders among workers in an industrial town in Tamil Nadu",*Journal of Clinical and Diagnostic Research*, Vol.5, No.2, pp. 187-190.

7. Bhagat, R.S. and Krishnan, B. (2010), "Organizational stress, psychological strain and work outcomes in six national contexts: A closer look at the moderating influences of coping styles and decision latitudes", *Cross Cultural Management: An International Journal,* Vol.17, No.1, pp. 10-29.

8. BLS (2004), "Bureau of labour statistics: Annual survey of occupational injuries and illnesses", *Bureau of Labour Statistics*, US.

9. Bodhare, T. and Valsangkar, S. (2011), "An epidemiological study of work-related musculoskeletal disorders among construction workers in Karimnagar, Andhra Pradesh",*Indian Journal of Community Medicine,*Vol.36, No.4, pp. 304-307.

10. Bongers, P.M., Winter,C.R., Kompier M.A. and Hildebrandt, V.H. (1993), "Psychosocial factors at work and musculoskeletal disease", *Scandinavian Journal of Work, Environment and Health,* Vol.19, No.5, pp. 297-312.

11. Bryman, A. and Cramer, D.(1999), *Quantitative Data analysis with SPSS Release 8 for Windows: A Guide for Social Scientists*, Routledge, London.

12. Buckle, P. and Devereux, J. (1999), *Work Related Neck and Upper Limb Musculoskeletal Disorders. Bilbao, Spain*: European Agency for Safety and Health at Work.

13. Buckle, P. (2005), "Ergonomics and musculoskeletal disorders: overview", *Occupational Medicine*, Vol. 55, No. 3, pp. 164-167.

14. Bureau of Labour Statistics (2004), *Lost-work time Injuries andIllnesses: Characteristics and Resulting Time Away From Work,*U.S. Department of Labour, Available from: www.dol.gov., Accessed on 17^{th} November 2011.

15. Burke, R.J. and Greenglass, E. (1991), *The relationship between stress and coping among Type* As. In P.L. Perrew (Ed.) Handbook of Job Stress.

16. Camara, A.S. (1991),"Formulation of system dynamics models",*Proceedings of the International System Dynamics Conference*, Bangkok, Thailand, pp. 82-97.

17. Caruso, C.C. and Waters, T.R. (2008), "A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector", *Industrial Health*, Vol. 46, No. 6, pp. 523-534.

18. Chen, W. (2005), "Impact of occupational stress and other psychological factors on musculoskeletal pain among Chinese offshore oil installation workers", *Occupational Environmental Medicine*, Vol. 62, No. 4, pp. 251-256.

19. Child, D. (1990), *The Essentials of Factor Analysis*, 2^{nd}Edition, Cassel Educational Limited, London.

20. Clark, L.A. and Watson, D. (1991), "Tripartite model of anxiety and depression: Psychometric evidence and taxonomic implications", *Journal of Abnormal Psychology*, Vol.100, No.12, pp. 316-336.

21. Cobb, S. (1976), "Social support as a moderator of life stress", *Psychosomatic Medicine*, Vol. 38, No. 5, pp. 300-314.

22. Cox, T., Griffiths, A. and Rial-Gonzalez, E. (2000), *Research on work related stress*, European Agency for Safety and Health at Work.

23. Cook, C.W. and Hunsaker, P.L.(2001), *Management and Organizational Behavior*, 3rd Edition, McGraw Hill, New York.

24. Cordes, C. and Dougherty, T. (1993), "A review and an integration of research on job burnout", *Academy of Management Review*, Vol. 18, No. 4, pp. 621- 656.

25. Coyle, R.G. (1996), *System Dynamics Modelling: A Practical Approach,* Vol. 1, Chapman & Hall.

26. Crawford, J.O. and Bolas, S.M. (1996), "Sick building syndrome, work factors and occupational stress",*Cross Cultural Management: An International Journal,*Vol. 22, No. 4, pp. 243-250.

27. Cronbach, L.J. (1951),"Coefficient alpha and the internal structures of tests", *Psychometrika*, Vol. 16, No. 3, pp. 97-334.

28. De Jonge, J., Dormann, C., Janssen, P.P.M., Dollard, M.F., Landeweerd, J.A. and Nijhuis, F.J.N. (2001), "Testing reciprocal relationships between job characteristics and psychological well-being:

A cross-lagged structural equation model", *Journal of Occupational and Organizational Psychology,* Vol. 74, No. 1, pp. 29-46.

29. De Lange, A.H., Taris, T.W., Kompier, M.A.J., Houtman, I.L.D. and Bongers, P.M. (2004), "The relationships between work characteristics and mental health: examining normal, reversed and reciprocal relationships in a 4-wave study", *Work & Stress: An International Journal of Work, Health & Organisations,* Vol. 18, No. 2, pp.149-166.

30. Dollard, M.F., Winefield, A.H. and Winefield, H.R. (2003), *Occupational stress in the service profession,* New York: Taylor & Francis.

31. Dyer, G.N., Hanges, J.P. and Hall, J.R. (2005), "Applying multilevel confirmatory factor analysis techniques to the study of leadership", *The Leadership Quarterly*, Vol. 16, pp. 149-167.

32. Edwards, J.R. (1992), "A cybernetic theory of stress, coping, and well-being in organizations", Academy *of Management Review"*, Vol. 17, No.2, pp. 238-274.

33. Elangovan, A.R. (2001) "Causal ordering of stress, satisfaction and commitment, and intention to quit: a structural equations analysis", *Leadership & Organization Development Journal*, Vol. 22, No. 4, pp.159-165.

34. Elias, A.A. (2008), "Energy efficiency in New Zealand's residential sector: A systemic analysis", *Energy Policy*, Vol. 36, No.9, pp. 3278- 3285.

35. Elias, A.A. (2012), "A system dynamics model for stakeholder analysis in environmental conflicts", *Journal of Environmental Planning and Management*, Vol.55, No.3, pp. 387-406.

36. Eugene, J.W. (1999), "The impact of work resources on job stress among correctional treatment staff", *Journal of Addictions and Offender Counseling*, Vol.20, No.1, pp. 26-34.

37. Eysenck, H. J. and Eysenck, M. (1985), *Personality and individual differences,* Plenum, London.

38. Fisher, C. and Gitelson, R. (1983), "A meta-analysis of role conflict and ambiguity", *Journal of Applied Psychology*, Vol. 68, No. 2, pp. 320—333.

39. Forrester, J.W. (1961), "The model versus modeling process", *System Dynamics Review*, Vol.1, No.2, pp. 133-134.

40. Gass, S.I. (1983), "Decision-aiding models: validation, assessment, and related issues for policy analysis", *Operations Research,* Vol.31, No.4, pp. 603-631.

41. Geer, J.G. (1991), "Do open-ended questions measure "salient" issues?",*Public Opinion Quarterly*, Vol.55, No.3,pp. 360-370.

42. George, D. and Mallery, P. (2009), *SPSS for Windows step by step: A simple guide and Reference, 17.0 update,* 10th Edition, Boston: Allyn and Bacon.

43. Ghosh, T. and Das, B. (2010), "Work-related Musculoskeletal Disorder: An Occupational Disorder of the Goldsmiths in India", *Indian Journal of Community Medicine*, Vol. 35, No. 2, pp. 321–325.

44. Goldberger, L. and Brenitz, S. (1993), *Handbook of stress: Theoretical and clinicalaspects*, pp. 656 – 676, 2nd Edition, New York: Free Press.

45. Gray-Toft, P. and Anderson, J.G. (1981), "Stress among hospital nursing staff: Its causes and effects", *Social Sciences & Medicine Part A*, Vol.15, No.5,pp. 639-647.

46. Greenhaus, J.H. and Beutell, N.J. (1985), "Sources of conflict between work and family roles", *Academy of Management Review*, Vol.12, No.6,pp. 120-128.

47. Hair, J.H., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998), Multivariate *Data Analysis*, Prentice-Hall, New Jersey.

48. Hamel, K. and Bracken, D. (1986), "Factor structure of the job stress questionnaire (JSQ) in three occupational groups", *Educational and Psychological Measurements,* Vol. 46, No. 3, pp. 777-786.

49. Harris, J.A., Saltstone, R. and Fraboni, M. (1999), "An evaluation of the job stress questionnaire with a sample of entrepreneurs", *Journal of Business and Psychology,* Vol. 13, No. 3, pp. 447-455.

50. Haukka, E., Leino-Arjas, P., Ojajarvi, P., Takala, E.P., Viikari-Juntura, E. and Riihimaki, H. (2011), "Mental stress and psychosocial factors at work in relation to multiple-site

musculoskeletal pain: A longitudinal study of kitchen workers", European *Journal of Pain*, Vol. 15, pp. 432-438.

51. Hayes, B.E., Perander, J., Smecko, T. and Trask, J. (1998), "Measuring perceptions of workplace safety: Development and validation of the work safety scale", *Journal of Safety Research*, Vol.29, No. 3, pp. 145-161.

52. Hicks, R., Fujiwara, D. and Bahr, M. (2006), "Confirmatory factor analysis of the occupational stress inventory-revised among Australian teachers", *ACSPRI Social Science Methodology Conference*, Sydney, Australia, pp. 11- 12.

53. Hildebrandt, V. (1995), "Musculoskeletal symptoms and workload in 12 branches of Dutch agriculture", *Ergonomics,* Vol. 38, pp. 2576–87.

54. Hoe, S.L. (2008), "Issues and procedures in adopting structural equation modeling technique", *Journal of Applied Quantitative Methods*, Vol.13, No.1, pp. 76-83.

55. Hofmann, D.A., Jacobs, R. and Landy, F. (1995), "High reliability process industries: Individual, micro, and macro organizational influences on safety performance"*, Journal of Safety Research*, Vol. 26, No.3, pp. 131-149.

56. Hu, L.T. and Bentler, P.M. (1999), "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives", *Structural Equation Modeling*, Vol.6, No.1,pp. 1-55.

57. Hurrell, J. J. Jr. and McLaney, M. (1988), "Exposure to job stress-a new psychometric instrument", *Scandinavian Journal of Work Environment and Health,* Vol. 14, No.1, pp. 27-28.

58. ILO (1986), "Psychosocial factors at work: Recognition and control", *Occupational Safety and Health Series No.56, InternationalLabour Organization, Geneva,* 1-81.

59. Jamal, M. (1984), "Job stress and job performance controversy: An empirical assessment", *Organizational Behavior and Human Performance*, Vol. 33, No. 1, pp. 1-21.

60. Janes, J. (1999), "Survey construction", *Library Hi Tech*, Vol.17, No.3, pp. 321-325.

61. Jones, J.R., Hodgson, J.T., Clegg, T.A. and Elliot, R.C. (1998), Self-*Reported Work-Related Illness In 1995: Results From A Household Survey*, Sudbury: HSE Books.

62. Jones, F.I. and Kinman, G. (2001), *Approaches to studying stress. In F.I. Jones & J. Bright (Eds), Stress: Myth, theory and research,.* Harlow, UK: Prentice Hall.

63. Joshi, T.K., Menon, K.K. and Kishore, J. (2001), "Musculoskeletal disorders in industrial works of Delhi", *International Journal of Occupational and Environmental Health*, Vol.7, No.3, pp. 217-221.

64. Kahn, R.L., Wolfe, D.M., Quinn, R.E., Snoek, J.D. and Rosenthal, R.A. (1964), *Organizational Stress: Studies In Role Conflict and Ambiguity,* New York: Wiley.

65. Kahn, R.L. and Cooper, C.L. (1993), *Stress in the Dealing Room: High performers under pressure, Routledge*, London and New York.

66. Keijsers, G., Schaufeli, W., Le Blanc, P., Zwerts, C. and Miranda, D.(1995), "Performance and burnout in intensive care units", *Work and Stress*, Vol. 9, No.4, pp. 513-527.

67. Kiani, F. and Samavtyan, H. (2012), "How safety trainings decrease perceived job stress: the effects of improvement in employee's attitude toward safety issues", Far *East Journal of Psychology and Business,*Vol. 6, No. 1, pp. 46-58.

68. Kletz, T.A. (1985), An *engineer's view of human error,* The Institution of Chemical Engineers, Warwickshire, England.

69. Kornhauser, A. (1965), *Mental Health of the Industrial Worker*, The University of Chicago Press, Chicago, Illinois.

70. Kuorinka, I. (1979), "*Occupational strain from working movements",* Paper to International Ergonomics Association, Warsaw, Abstract in: Ergonomics 22.

71. Kyriacou, C. (1989), *The nature and prevalence of teacher stress.* In Cole, M. and Walker, S. (Ed.), Teaching and Stress, Milton Keynes: Open University Press, pp. 27-34.

72. Lamontagne, A.D., Keegel, T., Louie, A.M., Ostry, M. and Landsbergis, P.A. (2007),"A systematic review of the job-stress intervention evaluation literature, 1990-2005", *International*

Journal of Occupational and Environmental Health, Vol. 13, No. 3, pp. 268-280.

73. Lazarus, R.S. (1999), *Stress and emotion: A new synthesis*, Springer, New York.

74. Levin, R.L., Van Sell, M. and Rubin, B. (1985), "A model of burnout in the work place", *The 3rd International Conference of the System Dynamics Society*, Keystone, USA.

75. Lipscomb, J.A., Trinkoff, A.M., Geiger-Brown, J. andBrady, B. (2002), "Work-schedule characteristics and reported musculoskeletal disorders of registered nurses", *Scandinavian Journal of Work, Environment & Health,* Vol.28, No.6, pp. 394-401.

76. Maani, K.E. and Cavana, R.Y. (2000), *Systems Thinking and Modelling: Understanding Change and Complexity*, Prentice Hall, New Zealand.

77. Mardia, K.V. (1970), "Measures of multivariate skewness and kurtosis with applications", *Biometrika*, Vol.57, No.3,pp. 519-530.

78. MacKinnon, N.J. (1978),"Role strain: Assessment of a measure and its invariance of factor structure across studies", *Journal of Applied Psychology*, Vol. 63, pp. 321-328.

79. Maslach, C., Jackson, S. and Leiter, M. (1996), *Maslach Burnout Inventory Manual*, Palo Alto: Consulting Psychologists Press.

80. McClelland, S.B. (1994), "Training needs assessment data-gathering methods: Part I, Survey questionnaires", *Journal of European Industrial Training*, Vol.18, No.1, pp. 22-26.

81. Menon, B.G. and Mahanty, B. (2012), "Effects of fuel efficiency improvements in personal transportation: Case of four-wheelers in India", *International Journal of Energy Sector Management*, Vol.6, No.3, pp. 397-416.

82. Menon, B.G. and Mahanty, B.(2013), "*Modeling the effects of fuel efficiency improvements in personal transportation in India",* Thesis of Department of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur, India.

83. Miller, K. andEllis, B.H. (1990), "An integrated model of communication, stress and burnout in the workplace", *Communication Research*, Vol.17, No.3, pp. 27-300.

84. Michie, S. (2002), "Causes and Management of Stress", *Occupational and Environmental Medicine,* Vol. 59, No. 1, pp. 67-75.

85. Mohan, G. M. and Elangovan, S. (2008), "Prevalence of job strain among Indian foundry shop floor workers", *Work,* Vol. 30, No.4, pp. 353-357.

86. Mohapatra, P.K.J., Mandal, P. and Bora, M.C. (1994), *Introduction to System Dynamics Modeling*, University Press, India.

87. Morecroft, J.D. (1982), "A critical review of diagramming tools for conceptualizing feedback system models", *Dynamica*, Vol.8, No.1, pp. 20-29.

88. Motowidlo, S., Manning, M. and Packard, J.(1986),"Occupational stress: Its causes and consequences for job performance", *Journal of AppliedPsychology,*Vol. 71, No. 4, pp. 618-629.

89. Nag, A. and Vyas, H. (2010), "Gender Differences, Work Stressors and Musculoskeletal Disorders in Weaving Industries", *Industrial Health*, Vol. 48, pp. 339–348.

90. National Research Council (2006), *"Panel on Musculoskeletal Disorders and the Workplace. Magnitude of occupationally-related musculoskeletal disorders",* In: Marras WS, KarwowskiW, eds. Fundamentals and assessment tools for occupational ergonomics. Occupational ergonomics handbook. 2nd Edition, New York: Taylor & Francis, 2-21.

91. NIOSH (1988), *The Generic Job Stress Questionnaire,* Centrefor Disease Control and Prevention, U.S. Department of Health and Human Services.

92. NIOSH (1999), *Stress at work*, Centre for Disease Control and Prevention, U.S. Department of Health and Human Services, Vol.99, No.101, pp. 1-26.

93. NIOSH (2001), *National Occupational Research Agenda for Musculoskeletal Disorders,* Cincinati. Available from: www.niosh.com., Accessed on 11th April, 2011.

94. Noblet, A. and Lamontagne, A.D. (2006), "The role of workplace health promotion in addressing job stress", *Health Promotion International*, Vol.21, No.4,pp. 346-353.

95. Nunnally, J. C. (1978), *Psychometric Theory*, 2nd Edition, New York: McGraw-Hill.

96. Nunnally, J.C. and Bernstein, I.H. (1994), *Psychometric Theory*, 3rd Edition, McGraw-Hill, New York.

97. O'Driscoll, M.P. andBeehr, T.A. (2000), "Moderating effects of perceived control and need for clarity on the relationships between role stressors and employee affective reactions", *Journal of Social Psychology*, Vol.140, No.2, pp. 151-159.

98. Ory, D.T. and Mokhtarian, P.L. (2009), "Modeling the structural relationships among short-distance travel amounts, perceptions, affections, and desires", *Transportation Research Part A*, Vol. 43, No.1, pp. 26-43.

99. Osipow, S.H. andDavis, A. (1998), *OccupationalStress Inventory* - Revised Edition, Professional Manual, Odessa, FL: Psychological Assessment Resources.

100. Palmer, S., Cooper, C. and Thomas, K.(2003), *Creating a Balance: Managing Stress,*The British Library, London.

101. Punnett, L., Fine, L.J.,Keyserling, W.M., Herrin, G.D. and Chaffin, D.B. (2000), "Shoulder disorders and postural stress in automobile assembly work", *Scandinavian Journal of Work, Environment and Health,* Vol. 26, pp. 283–91.

102. Qudrat-Ullah, H. and Seong, B.S. (2010), "How to do structural validity of a system dynamics type simulation model: The case of an energy policy model", Energy *Policy*, Vol. 38, No.5, pp. 2216-2224.

103. Ram, N. and Khoso, I. (2011),"Role conflict and role ambiguity as factors in work stress among managers", *Asian Social Science*, Vol. 7, No. 2, pp. 113-118.

104. Raykov, T. andMarcoulides, G.A. (2008), An *Introduction to Applied Multivariate Analysis*, Routledge: Taylor & Francis Group, New York.

105. Richardson, G.P. (1985), "Problems with causal-loop diagrams", *System Dynamics Review*, Vol.2, No.2, pp. 158-170.

106. Robbins, S.P. (2001), *Organizational Behavior*, 9thEdition, Prentice-Hall Inc, New Jersey.

107. Roberts, J.A., Lapidus, R.A. andChonko, L.B. (1997),"Salesperson and stress: The moderating role of locus of control on work stressors and felt stress", *JournalofMarketing Theory and Practice*, Vol.5, No.3, pp. 93-108.

108. Roger, D. and Najarian, B. (1998), "The relationship between emotional rumination and cortisol secretion under stress. "*Personality and Individual Differences"*, Vol. 24, pp. 531-534.

109. Rundmo, T. (1992), "Risk perception and safety on offshore petroleum platforms - Part II: Perceived risk, job stress and accidents", *Safety Science*, Vol.15, No.1, 53-68.

110. Saeed, K. (1998), "*Defining a problem or constructing a reference mode*", Proceedings of the 16th International Conference of the System Dynamics Society, Quebec City, Canada, pp. 1-29.

111. Sager, J.K. (1994), "A structural model depicting salespeople's job stress", *Journal of the Academy of Marketing Sciences,* Vol. 22, No. 1, pp. 74-84.

112. Selye, H. (1936), "A syndrome produced by diverse noxious agents", *Nature*, Vol. 138, No. 32, pp. 32–35.

113. Shah, R. and Goldstein, S.M. (2006), "Use of structural equation modeling in operations management research: Looking back and forward', *Journal of Operations Management*, Vol. 24, No.2, pp. 148-169.

114. Sharma, S. (1985), "Well-being and organizational stress: A case for cross-cultural study of correlates and moderators", *Social Science International*, Vol. 1, pp. 20-32.

115. Siegrist, J. (2001), A Theory of occupational stress, In J. Dunham (Ed.) Stress in the workplace, Philadelphia, PA: Whurr, pp. 52-66.

116. Silvian, S.P. and Maiya, A. (2011),"Antecedents of work related musculoskeletal disorders in software professionals",*International Journal of Enterprise Network Management*, Vol.4, No.3, pp. 247-260.

117. Singh, S. and Arora, R. (2010), "Ergonomic Intervention for Preventing Musculoskeletal Disorders among Farm Women", *Journal of Agricultural Science*, Vol.1, No.2, pp. 61-71.

118. Singh, J. and Lal, H. (2012), "Musculoskeletal Disorder Risk Assessment in small scale forging Industry by using RULA

Method", *International Journal of Engineering and Advanced Technology,*Vol.1, No. 5, pp. 513-518.

119. Sirajunisa, K. and Panchanatham, N. (2011),"Influences of Occupational Stress on Work Life Balance among Women Professionals", *The Journal of Commerce,*Vol. 2, pp. 44-57.

120. Spallek, M. and Kuhn, W. (2010), "Work-related musculoskeletal disorders in the automotive industry due to repetitive work - implications for rehabilitation', *Journal of Occupational Medicine and Toxicology,* Vol.5, No.6, pp. 414-420.

121. Spector, P. (2000), *Industrial & Organizational Psychology: Research and Practice*, 2nd Edition, John Wiley & Sons, New York.

122. Stepp, M.D., Winebrake, J.J., Hawker, J.S. and Skerlos, S.J. (2009), "Greenhouse gas mitigation policies and the transportation sector: The role of feedback effects on policy effectiveness", *Energy Policy*, Vol. 37, No. 7, pp. 2774-2787.

123. Sterman, J.D. (2000), Business *Dynamics: Systems Thinking and Modeling for a Complex World*, McGraw-Hill, New York.

124. Sterman, J.D. (2008), "Risk Communication on Climate: Mental Models and Mass Balance", *Science*, Vol. 322, pp. 532-533.

125. Sureshchandar, G.S., Rajendran, C. and Anantharaman (2001), "A conceptual model for total quality management in service organisations", *Total Quality Management*, Vol.12, No. 3, pp. 343-363.

126. Sutherland, V.J. and Cooper, C.L.(2000), *Strategic Stress Management*, Palgrave Publishers, London.

127. Teja, J.S. (1978),"Mental illness and the family in America and India", *Journal of Social Psychiatry,* Vol.24, No.3, pp. 225-31.

128. Thomas, W. and Colligan, M.S.W. (2006), "Occupational stress in organizations", *Journal of Workplace Behavioural Health*, Vol. 21, No. 2, pp. 89-97.

129. Torkzadeha, G., Koufterosb, X. and Doll, W.J. (2005), "Confirmatory factor analysis and factorial invariance of the impact of information technology instrument", *Omega*, Vol. 33, No. 2, pp. 107-118.

130. Van der Hek, H. and Plomp, H.N. (1997), "Occupational stress management programmes: a practical overview of published effect studies", *Occupational Medicine,*Vol.47, No.3, pp. 133-141.

131. Van Dick, R. and Wagner, U. (2001), "Stress and strain in teaching: A structural equation approach", *British Journal of Educational Psychology,* Vol. 71, No. 2, pp. 243-259.

132. Vinodkumar, M.N. and Bhasi, M. (2009), "Safety climate factors and its relationship with accidents and personal attributes in the chemical industry", Safety *Science*, Vol. 47, No. 5, pp. 659-667.

133. Vinodkumar, M.N. and Bhasi, M. (2010), "Safety management practices and safety behaviour: Assessing the mediating role of safety knowledge and motivation", *Accident Analysis and Prevention",* Vol. 42, No. 6, pp. 2082-2093.

134. Von Onciul, J. (1996), "Stress at Work", British *Medical Journal*, Vol. 313, pp. 745-748.

135. Warr, P.B. (2007), "Decision latitude,job demands and employee well-being", *Work and Stress: An International Journal of Work, Health and Organizations,*Vol. 4,No. 4, pp. 285-294.

136. Warren, N. (2001), "Work stress and musculoskeletal disorder etiology: The relative roles of psychosocial and physical risk factors", *Work: A Journal of Prevention, Assessment and Rehabilitation,* Vol. 17, No. 3, pp. 221-234.

137. Waters, J. A. and Ussery, W. (2007), "Police stress: History, contributing factors, symptoms, and interventions", *Policing: An International Journal of Police Strategies and Management*, Vol.30, No.2, pp. 169–188.

138. Weevers, H.J., van der Beek, A.J.,Anema, J.R., van der Wal, G. andvan Mechelen, W. (2005),"Work-related disease in general practice: a systematic review", *Family Practice,*Vol.22, No.2, pp. 197-204.

139. Westgaard, R.H. and Winkel, J. (1997), "Ergonomic intervention research for improved musculoskeletal health: a critical review", International *Journalof Industrial Ergonomics*, Vol. 20, No. 6, pp. 463–500.

140. Westman, M. and Eden, D.(1996), "The inverted-U relationship between stress and performance: A field study", *Work and Stress*, Vol. 10, No. 2, pp. 165-173.

141. WHO (2007), "Raising awareness of stress at work in developing countries", *Protecting Worker's Health Series*, No.6.

142. Zastrow, C. (1984),"Understanding and preventing burn-out", *British Journal of Social Work*, Vol. 14, No. 1, pp. 141– 155.

143. Zohar, D (1994), "Analysis of job stress profile in the hotel industry", *International Journal of Hospitality Management*, Vol.13, No.3, pp. 219-231.

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APPENDIX

Appendix A – The Questionnaire

Name of the Company :

Designation :

Work Experience :

Educational Qualification :

Age :

What is your gender?

1. Male ☐ 2.Female ☐

What is your marital status?

1. Married ☐ 2.Unmarried ☐ 3.Single, divorced ☐ 4.Single, widowed ☐

Please ☑ against only one appropriate answer for each question in the box provided

Q 1. I know clearly how much authority I have.

1. Very clear ☐ 2. Mostly clear ☐ 3. Slightly clear ☐ 4. Not clear ☐

Q 2. There are clear, planned goals and objectives for my job.

1. Very clear ☐ 2. Mostly clear ☐ 3. Slightly clear ☐ 4. Not clear ☐

Q 3. I know clearly what is expected of me.

1. Very clear ☐ 2. Mostly clear ☐ 3. Slightly clear ☐ 4. Not clear ☐

Q4. I have to bend or break a rule or policy in order to carry out an assignment.

1. Never ☐ 2. Occasionally ☐ 3. Sometimes☐ 4. Fairly often ☐

5. Very often ☐

Q5. I work with two or more groups who operate quite differently.

1. Never □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q6. I receive incompatible requests from two or more people.

1. Never □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q7. I receive an assignment without the help I need to complete it.

1. Never □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q8. The level of noise in the area (s) in which I work is high.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □
5. Strongly Agree □

Q9. The level of lighting in the area (s) in which I work is low.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □
5. Strongly Agree □

Q10. The temperature of my work area (s) is high.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □
5. Strongly Agree □

Q11. How often does your job require you to work very fast?

1. Rarely □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q12. How often does your job require you to work very hard?

1. Rarely □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q13. Do you have to sit on a chair or stool for one hour or more without a break?

1. Never □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □
5. Very often □

Q14. Do you use keyboard for more than one hour a day?

1. Never □ 2. Occasionally □ 3. Sometimes □ 4. Fairly often □

5. Very often □

Q15. In the past twelve months, I have been restricted from doing my routine job at least once due to some disabilities.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □

5. Strongly Agree □

Q16. In the past twelve months, my job has been a vector for my disability/disabilities

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □

5. Strongly Agree □

Q 17. How much can your immediate supervisor (boss) be relied on when things get tough at work?

1. Very much □ 2. Somewhat □ 3. A little □ 4. Not at all □

5. Don't have any such person □

Q18. How much can your spouse, friends and relatives be relied on when things get tough at work?

1. Very much □ 2. Somewhat □ 3. A little□ 4. Not at all □

5. Don't have any such person □

Q19. I have to do child care duties apart from my routine job.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □

5. Strongly Agree □

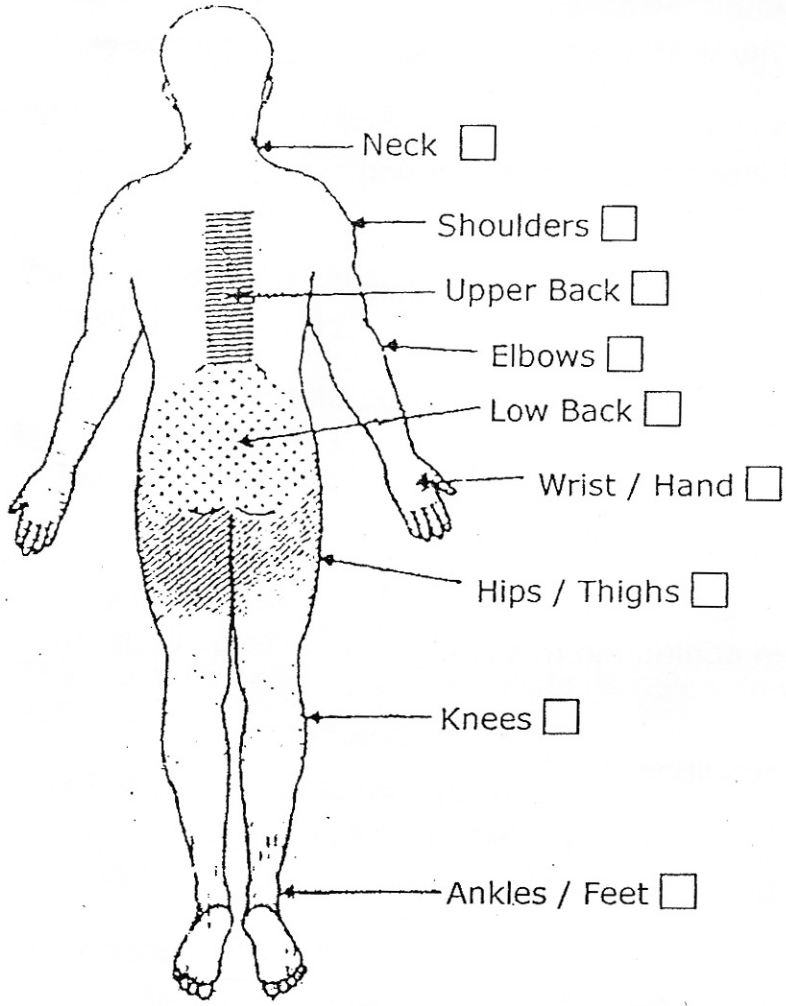
Q20. I have the primary responsibility for the care of elderly parents or disabled person on a regular basis.

1. Strongly disagree □ 2. Disagree □ 3. Neutral □ 4. Agree □

5. Strongly Agree □

Thank you for completing the questionnaire

Have you at any times during last 12 months had trouble on any of the parts of your body shown in the figure below? If your answer is "YES", please put a ✓ mark in the corresponding boxes.



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Appendix B - System Dynamics Model Equations

Job_Stress(t) = Job_Stress(t - dt) + (Stress_Increase_Rate - Stress_Release_Rate) * dt

INIT Job_Stress = 1

INFLOWS:

Stress_Increase_Rate = Job_Induced_Anxiety*Job_Involvement*Physical_Work_Factors*Work_Environment*
2.5

OUTFLOWS:

Stress_Release_Rate = Job_Stress

Absenteesm = Job_Stress*WRMSD_Fraction

Job_Induced_Anxiety = Neuroticism*Rumination

Job_Involvement = Job_Satisfaction/Absenteesm

Job_Satisfaction = (Job_Security/Job_Induced_Anxiety)*3.5

Job_Security = Absenteesm/1.25

Neuroticism = Role_Ambiguity/Role_Conflict

Rumination = Neuroticism/Job_Security

Structure = Supervisor's_Performance/0.3

WRMSD_Fraction = 3

Physical_Work_Factors = GRAPH(TIME)

(0.00, 0.00), (1.00, 0.195), (2.00, 0.325), (3.00, 0.445), (4.00, 0.53), (5.00, 0.595), (6.00, 0.655), (7.00, 0.715), (8.00, 0.77), (9.00, 0.815), (10.0, 0.865), (11.0, 0.915), (12.0, 0.975)

Role_Ambiguity = GRAPH(Structure)

(0.00, 0.035), (20.0, 1.09), (40.0, 2.38), (60.0, 3.61), (80.0, 4.52), (100, 5.32), (120, 6.06), (140, 6.51), (160, 6.83), (180, 6.93), (200, 7.00)

Role_Conflict = GRAPH(Structure)

(0.00, 0.01), (20.0, 0.175), (40.0, 0.44), (60.0, 0.595), (80.0, 0.7), (100, 0.785), (120, 0.84), (140, 0.89), (160, 0.94), (180, 0.98), (200, 0.995)

Supervisor's_Performance = GRAPH(TIME)

(0.00, 0.00), (1.00, 1.00), (2.00, 4.00), (3.00, 6.00), (4.00, 10.5), (5.00, 15.5), (6.00, 22.5), (7.00, 31.5), (8.00, 42.5), (9.00, 52.0), (10.0, 68.0), (11.0, 83.0), (12.0, 95.5)

Work_Environment = GRAPH(TIME)

(0.00, 0.005), (1.00, 0.02), (2.00, 0.04), (3.00, 0.06), (4.00, 0.09), (5.00, 0.12), (6.00, 0.145), (7.00, 0.19), (8.00, 0.29), (9.00, 0.385), (10.0, 0.5), (11.0, 0.66), (12.0, 0.985

LIST OF PUBLICATIONS

Praveensal, C.J., Menon, B.G. and Madhu, G. (2013), "Determinants of job stress in Indian chemical process industry: A factor analysis approach", *Work & Stress. (Under review)*

Praveensal, C.J., Menon, B.G. and Madhu, G. (2013), "System dynamics modeling of the influence of job stress on musculoskeletal disorders in chemical process industries", *International Journal of Industrial Ergonomics*. *(Communicated)*

Curriculum Vitae

The author of this thesis, Praveensal C J was born in 1975 in Chalakkudy, Thrissur district of Kerala, India. He obtained his Bachelor of Technology degree in Mechanical Engineering in the year 1997 from LBS Engineering College, Kasaragod, Kerala and Master of Technology degree in Production Engineering in the year 2006 from Cochin University of Science and Technology, Kerala, India. He has about 13 years of experience in teaching. He started his career as Assistant Engineer in Merchant Navy, sailing with Pacific International Lines, Singapore. Since 2001, he is working in SCMS School of Engineering and Technology (SSET), Angamali, Kerala, India. Presently he is working as Associate Professor in the Department of Mechanical Engineering of SSET. The author joined the Division of Safety and Fire Engineering, School of Engineering, Cochin University of Science and Technology, in September 2007, as a doctoral student. His areas of interest include Human Factors Engineering, System Dynamics and Policy Planning, Applied Multivariate Statistical Analysis, Total Quality Management and Reliability Engineering.