Examining the empirical relationship between subjective fatigue and employee work engagement in a heavy workload manufacturing environment

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This thesis is dedicated to my parents Mr. G.S. Balasubramanian and Mrs. Subha Balasubramanian, my sister Ms. Madhushita and the rest of my family and friends for their love, support and encouragement.

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Abstract

The purpose of this study was to examine the empirical relationship between Subjective Fatigue and Employee work engagement among employees working under heavy workload conditions in Tennessee, USA. The questionnaire was developed by reviewing extant literature and the factors that were chosen were subjected to exploratory factor analysis. Post elimination of the weakly loaded factors, a questionnaire based on the selected factors was designed to measure the subjective levels of fatigue. The data was collected from two manufacturing company sites from East Tennessee and was subjected to analysis using IBM SPSS and SmartPLS softwares. As a part of the SEM analysis, a causal model was built to determine the existence of the relationship between subjective fatigue and employee work engagement. The model aimed at determining whether a correlation and causality were present between the two constructs. The results suggested that a correlation between subjective fatigue and employee engagement does exist, but a unidirectional causality between the two does not. In other words, high levels of subjective fatigue do not directly impact the engagement levels of employees.

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Chapter 1

Introduction

1.1 Background and Motivation

Employee fatigue is a growing concern for companies and industries alike. A survey conducted by the National Safety Council [NSC, 2017] reports that close to 97% of American workers are at a risk of fatigue.

The term "Fatigue" can be used to describe several symptoms such as (a) lack of sleep attributing to "tiredness" [Shen et al., 2006]; (b) whole body fatigue[Davila et al., 2010]; (c) localized muscle fatigue[Chaffin, 1973]; (d) mental fatigue/exhaustion as defined by Van der Linden et al. [2003] "as a change in psycho-physiological state due to sustained performance" and (e) effects that are associated with ailments like cancer, Parkinson's disease, depression, anxiety and multiple sclerosis[Dittner et al., 2004]. Despite the years of fatigue research, a consensus in the definition and measure has not been articulated owing to the debate over its nature and dimensionality. Before we dive into the implications of how fatigue affects employees and businesses, it is vital that we understand the term by its meaning.

1.1.1 Fatigue

The term 'Fatigue' is of both Latin and French origin [Ream and Richardson, 1996]. 'Fatigare' in Latin means " to exhaust as with riding or working, to weary or to harass". The French word 'Fatiguer' means to tire.

Fatigue can be a result of multiple causes and conditions ranging from medical ailments such as musculoskeletal disorders, cancer, autoimmune diseases, bacterial and viral infections; to physiological states such as sleep deprivation and intense muscular activity; and psychological states such as depression, anxiety and somatoform disorders. Fatigue can also result from unhealthy sleep cycles that could offset the circadian rhythm, excessive alcohol and caffeine consumption and other psychological states like post-traumatic stress disorder (PTSD) [Manu et al., 1992]. The effects of fatigue are prevalent in general population as well.

Fatigue has a lasting impact on an individual's long term clinical well-being. Occupational Safety and Health Administration (OSHA) lists the ill effects fatigue can have on an individual, ranging from heart disease, stomach and digestive problems, musculoskeletal disorders, reproductive problems, depression, certain cancer types to sleeping disorders.

Apart from the deleterious effects fatigue has on an individual clinically, it has a direct and considerable impact on companies and industries on cost, lost work hours and injuries. According to Ricci et al. [2007], fatigue among employees costs employers $136.4 billion annually in lost productive time and other health related costs. A 2014 meta-analysis conducted by NSC [2017] in 2017 revealed that an estimated 13% of the workplace accidents/injuries can be attributed to fatigue.

Fatigue also negatively affects safety in the workplace. OSHA [2009] reports that fatigue was a major contributing factor in Industrial disasters such as the 2005 Texas City BP oil refinery explosion, the 2009 Colgan Air Crash, the explosion of the space shuttle Challenger and the nuclear accidents at Chernobyl and Three Mile Island.

A nationwide survey conducted by NSC [2017] also reported that 74% of the employers underestimate the prevalence of fatigue in the workforce. The survey also showed that 47% of the employers had observed a decrease in employee productivity, 50% have had employees fall asleep during a job, 57% had reported absenteeism and 32% of employers had reported injuries and near misses due to fatigue. These recent reports show us that though our understanding of fatigue and its impacts have improved over the years, the problem still looms large. The manufacturing sector in the US accounts for 14% of the annual GDP of the US and 11% of the total employment in the country. A study conducted by Lu et al.

[2017] estimated the prevalence of fatigue in U.S manufacturing workers and reported that out of the 451 participants surveyed, 57.9% reported that they were fatigued 'during the past week'.

Fatigue in manufacturing is studied from the perspective that includes 'lack of energy', 'lack of sleep' and 'lack of motivation to perform tasks'. Hence, for this research, fatigue will be used to denote a state of "low energy levels", feeling of "tiredness", "lack of focus and motivation" that results from intense physical activity.

Fatigue is often expressed in "dimensions" and is either unidimensional or multidimensional. Before the 1990s, fatigue was widely considered to be a unidimensional construct [Lee et al., 1991]. After the mid 90's, most researchers conceived fatigue as a multidimensional construct [Smets et al., 1995, Hancock and Desmond, 2000]. For example, Smets et al. [1995] classified fatigue into five dimensions: general fatigue, physical fatigue, mental fatigue, reduction in activity, reduction in motivation. These 'dimensions' are collectively evaluated to assess the overall construct, 'fatigue'.

Presently, various techniques exist to evaluate fatigue which can be broadly classified into 'objective' and 'subjective' assessment [Shahid et al., 2010]. Objective assessment of fatigue aims at measuring the quantifiable effects of fatigue, whereas subjective assessment of fatigue aims at capturing the qualitative effects which captures the individual's perspective of the experience. Subjective fatigue can only be measured with the help of self-reported scales [Åhsberg et al., 1997]. One of the aims of this study is to measure subjective fatigue levels of employees working in heavy workload manufacturing environments.

Capturing the perspective of the individual in measuring subjective fatigue is crucial in evaluating the subjective well-being of that individual, hence the use of self-reported scales. Objective fatigue is the measurement of quantifiable fatigue related data with the help of widely used tests like Critical Flicker Fusion frequency (CFF) and Simple Reaction Time (SRT). Although objective fatigue measurement is more quantitative, it does not capture the perspective of the individual experiencing fatigue. Subjective fatigue on the other hand uses self-assessment questionnaires or scales that prompt to provide information on the impact and intensity of certain fatigue consequences. For example, assuming sleepiness is a

consequence of fatigue, the instrument may contain one or multiple questions related to the perception of sleepiness.

The ability of these instruments to be valid and reliable, largely depends on framing questions and the individual's ability to assess ones own magnitude of sleepiness. The following paragraph talks about a condition that is often related to and compared with fatigue, "Burnout".

1.1.2 Burnout

While discussing fatigue, it is important to discuss a similar condition that is often compared, equated with and differentiated from, "Burnout". It is characterized with the help of three dimensions, namely exhaustion, inefficacy and cynicism [Maslach, 1997]. Often, burnout is associated with work-related factors and has a psychological background [Schaufeli and Taris, 2005].

1.1.3 Work Engagement

Apart from subjective fatigue, this research focuses on another concept, 'employee work engagement'. Employee engagement as conceptualized by Kahn [1990], is the ability of an individual to be physically, cognitively and emotionally be engaged to ones work and intends to continue their role in the organization. A more precise definition of work engagement was developed by Schaufeli et al. [2002], which states that work engagement is a work-related state characterized by vigor, dedication and absorption. Schaufeli et al. [2002] created a scale to estimate the engagement levels of the employees characterized by vigor, dedication and absorption. The scale was named as the "Utrecht Work Engagement Scale" (UWES) and contained 17 items connected to three factors. Upon further investigation of the construct validity and the yield of results, the author proposed an abridged scale with just 9 items with 3 items loading on each factor.

1.1.4 Effects of Burnout on Engagement

Among the many things that burnout affects, the core dimensions of employee engagement are known to be the exact opposites of the dimensions influencing burnout [González-Romá et al., 2006]. Also, according to Maslach et al. [1986], engagement which is characterized by energy, involvement and efficacy, is the exact opposite of burnout which is characterized by exhaustion, cynicism and inefficacy. The study conducted by Saks [2006] showed that burnout which is often associated with the Job Resource Model (JR-D) is a positive antecedent to work engagement. Though the sub-components of burnout and subjective fatigue are known to overlap, there are conditions in which these can evidently occur as separate conditions in severe health and work related conditions [Leone et al., 2007].

The relationship between subjective fatigue and employee engagement has not been established in literature. This study would examine if subjective fatigue and its underlying factors are antecedents to work engagement. By doing so, we gain insight into understanding the effects of factors contributing to low work engagement, in turn providing organizations a deeper understanding in dealing with employees showing low engagement levels.

1.2 Problem Statement

The aim of this research is to assess the causality between subjective fatigue and employee work engagement. Though research suggests multiple antecedents to employee work engagement [Saks, 2006], subjective fatigue, as a strong negative antecedent to employee engagement, is not found in literature. One of the contributions of this research is useful in finding the underlying correlation and causality between subjective fatigue and employee work engagement in a heavy workload manufacturing environment. This research also aims to develop a fatigue measurement tool capable of assessing subjective fatigue among people working in heavy workload environments. The following statement forms the hypothesis of this research.

H1 – Subjective fatigue has a significantly negative influence on employee work engagement.

If validated, this research will show the statistical relationship between subjective fatigue and employee engagement, which would help provide the empirical relationship between the two constructs. Also, moderating the effects of subjective fatigue will help companies that function in heavy workload conditions improve employee engagement and further the positive consequences of the same.

1.3 Approach

This research has two main objectives. The primary objective is to develop a fatigue scale capable of measuring subjective fatigue, the secondary objective is testing the correlation and causality between employee engagement and subjective fatigue. The following phases are the manner in which this research will be carried out. A pictorial representation of the approach is presented in Figure 1.1

- **Phase 1** includes researching and selecting the sub-components (factors) that constitute the 'subjective fatigue' construct. A set of questions are framed for each of those selected factors based on the variables that need to be measured. Literature search was performed to identify a suitable and validated work engagement scale that helps to measure employee work engagement.

- **Phase 2** filters the factors by conducting pilot of the developed survey on a random sample from the targeted population and the results are used to eliminate the weakly loaded factors and questions alike. The survey is then validated and refined which is then used for data collection.

- **Phase 3** outlines the data collection procedures. It is divided into 3 stages: Choosing and justifying the site for the survey application, data collection from the participants, coding and screening of the data.

- **Phase** 4 formulates the hypothesis model and frames the structural equations. A Structural Equation Model is built consisting of the measurement and the structural models that are set to be evaluated in the next phase.

- **Phase 5** evaluates the structural equation model in SmartPLS^{TM} to examine the correlation between factors within each construct and the causal effect among the two chosen constructs, Fatigue and Employee Work Engagement.
- **Phase 6** consolidates the results of the analysis and discusses the implications of the same. Furthermore, future work and conclusions are explained.

The scope of the research is explained in Section.1.4

1.4 Scope

- The survey developed in this research will be used to assess subjective fatigue levels of employees under heavy workload manufacturing environments.
- The result of the correlation and causality analysis will help companies better understand their employee's subjective fatigue and can look at ways to mediate the effects of the same.
- The variables considered in this research are limited to two types of fatigue, physical and mental.
- The study considers only specific factors from work related conditions.

1.5 Organization of the Thesis

This study is divided into five chapters. Chapter 1 contains the introduction, background, problem statement, approach and the scope of this research. Chapter 2 reviews the existing literature on fatigue, dimensionality of fatigue, subjective fatigue and existing antecedents of employee work engagement. Chapter 3 outlines the research methodology, research design, survey development and validation, data collection and building the structural equation model. Chapter 4 discusses the results of the data analysis, structural model analysis, correlation analysis and hypothesis testing. Discussions and the implications of the results will be included at the end of the chapter. Chapter 5 will summarize the study, conclude and explain the findings and limitations along with the future research.

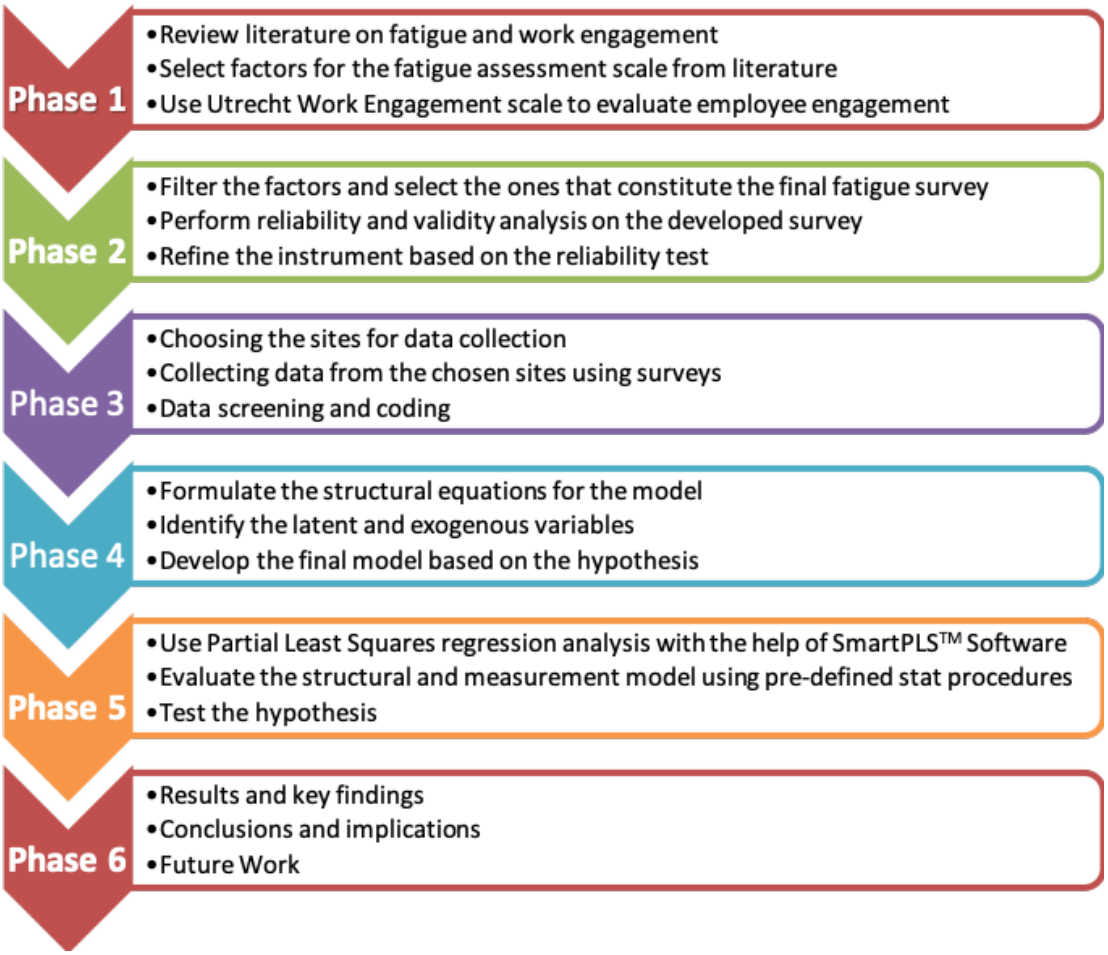

Figure 1.1: Research Approach.

Chapter 2

Literature Review

Occupational Fatigue has been a long standing problem in workplaces and is becoming a growing concern in many industries in the US and worldwide. This chapter presents selective literature that helps develop the groundwork in analyzing the correlation of employee fatigue and their engagement at work. The sources used for this literature search are:

- Journal papers indexed from Google Scholar and Scopus
- Journal papers, E-books and textbooks downloaded and accessed from University of Tennessee's OneSeach engine
- Reports generated by the Bureau of Labor Statistics and National Safety Council

Some of the keywords used as a part of the literature search is illustrated in Figure 2.1

2.1 Definitions of Fatigue

Past efforts in understanding fatigue has shown us that fatigue has remained an elusive topic in the field of science with multiple definitions being formulated over years of research. The term 'fatigue' can be traced all the way to medical literature where it was associated with harmful effects of overwork. A framework for fatigue was developed in the year 1875 by George Poore where he distinguishes general, local, acute and chronic fatigue [Rabinbach, 1992, Noy et al., 2011]. According to Grandjean [1979], fatigue is a term that "denotes

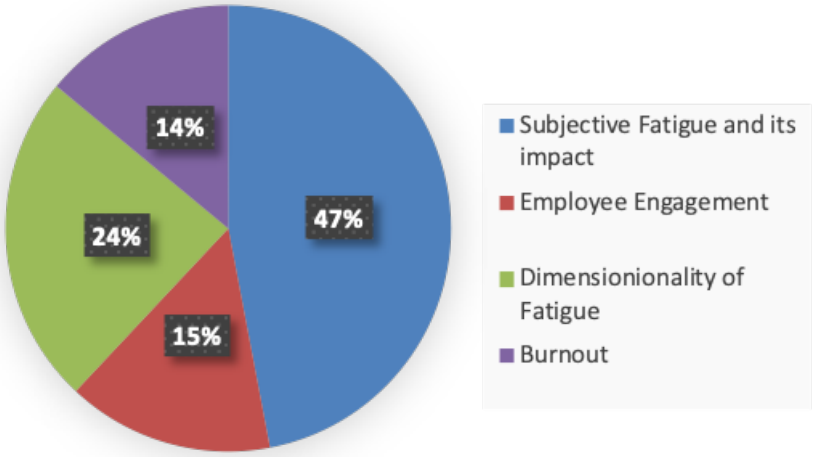

Figure 2.1: Keywords used in Literature Search.

a loss of efficiency, and a disinclination towards any kind of work". Another definition developed by the North American Nursing Diagnosis Association states that fatigue can be interpreted as "an overwhelming sustained sense of exhaustion and decreased capacity for physical and mental work". A broader definition of fatigue is defined by Lewis and Wessely [1992] as the expending of physical and mental strengths that result from physical or mental exertion. Table 2.1 presents a categorical summary of the multiple definitions of fatigue from the reviewed literature. It is clear from Table 2.1 that fatigue has multiple contextual interpretations and definitions. Despite the continued effort till date, fatigue does not have a gold standard as it was in 1921, when Muscio [1921] then stated, "the term fatigue be absolutely banished from precise scientific discussion, and consequently the attempts to obtain a fatigue test be abandoned". Researchers have found the need to conceptualize fatigue for the specific type of study and thus most definitions today have been scenario specific, each measuring different parts of the same fatigue "elephant" [Hancock and Verwey, 1997]. This lack of consensus in defining fatigue as a clear construct is partly due to the different opinions on its dimensionality which have been discussed in the next section.

2.1.1 Dimensionality of Fatigue

Dimension is a component of a complex construct [Polit and Beck, 2004]. Literature suggests that the dimensionality of fatigue has been a topic of debate for researchers over the years arguing that fatigue can either be unidimensional or multi-dimensional [Michielsen et al., 2004, Vercoulen, 1999].

Before 1990, fatigue was generally viewed as an unidimensional construct [Lee et al., 1991], i.e. explaining fatigue with a single dimension: psychological, physiological or social. A few examples of unidimensional constructs are: Visual Analog Scale (VAS) developed by Krupp et al. [1988]; a 10-item Fatigue Feeling Checklist developed by Pearson and Byars [1956]; Fatigue Severity Scale developed by Krupp et al. [1989]; and, a Profile of Mood States developed by Fawzy et al. [1990].

Nowadays, researchers perceive fatigue as a multi-dimensional construct [Hancock and Desmond, 2000, Smets et al., 1995]. For example, Smets et al. [1995] proposed five dimensions: general fatigue, physical fatigue, reduction in activity, reduction in

Table 2.1: Summary of Fatigue Definitions

Category	Definitions	Source
Physiological	"weakness... from repeated exertion or a decreased response of cells, tissues, or organs after excessive stimulation, stress or activity."	Hirshowitz (2013)
	"inability to function at the desired level due to incomplete recovery from the demands of prior work and other waking activities". Acute fatigue can occur when there is inadequate time to rest and recover from a work period. Cumulative (chronic) fatigue occurs when there is insufficient recovery from acute fatigue over time.	Gander (2011)
Subjective	"subjectively experienced disinclination to continue performing the task because of perceived reductions in efficiency."	Brown (1995)
Performance	"measurable decrements in performance of an activity caused by extended time performing it."	
	"a diminished capacity for work and possible decrements in attention, perception, decision making and skill performance." "decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in the memory."	Cercarelli (1996)
Multi-dimension	"There are three aspects to fatigue: physiological, objective (work decrement), and subjective fatigue."	
	"an individual's multi-dimensional physiological-cognitive state associated with stimulus repetition which results in a prolonged residence beyond a zone of performance comfort."	Hancock(1997)

motivation, and mental (cognitive) fatigue. Some researchers have deviated from the purely psychological/physiological approach towards fatigue and have developed a three dimensional fatigue construct: situation specific fatigue; consequences of fatigue; and response to sleep/rest [Schwartz et al., 1993].

The multidimensionality of fatigue has been established through the use of factor analysis [Kaiser, 1960]. Smets et al. [1995] tested for the dimensionality through factors analysis, with data collected from a heterogeneous group of cancer patients and found that both a five factor model and a four factor model showed good fit.

Åhsberg et al. [1997] developed the 'Swedish Occupational Fatigue Inventory' (SOFI) as a multidimensional fatigue assessment scale with 5 dimensions of fatigue. They tested the five factor model with data gathered from individuals working in different occupations and found that the model had a good fit [Åhsberg et al., 1997]. However, an exploratory study conducted by Studts [2001] failed to provide evidence of multidimensionality with the cognitive, emotional, somatic and the other factors of fatigue displaying no correlation. Thus, it is safe to say that there is no consensus on the definitions of fatigue and its dimensions.

There is a need to review techniques based on dimensionality to construct the fatigue measurement model. Currently, there are several measurement techniques that are used to assess fatigue and can be classified into 'objective' and 'subjective' measurements. These techniques are aimed at measuring fatigue, but the difference lies in the qualitative and quantitative data collected from a target population. Understanding the difference is important for this study as it would allow for a clear selection of the assessment technique. The following section outlines the theory and application behind the two approaches.

2.1.2 Objective vs Subjective Measurement of Fatigue

The measurement of fatigue can be done through both objective and subjective measurements [De Vries et al., 2003]. Subjective fatigue can be described as a "pervasive sense of tiredness or lack of energy that is not related exclusively to exertion" [Brown and Schutte, 2006]. Objective fatigue on the other hand has indicators that are quantifiable. Defined by Stokes et al. [1988] objective fatigue is the failure to maintain the required force or power

output during continuous and repeated muscle contraction or if an individual sees a gradual decline in the ability to perform mental tasks over a period of time.

Support for the existence of subjective and objective measurements is shown by Piper et al. [1987] who expressed fatigue in four dimensions: perception (subjective), biochemical, psychological and behavioral. The author classifies 3 of the total 4 factors as objective (biomedical, psychological, and behavioral). The author goes on and suggests that knowledge about the relationships between the objective (biochemical, psychological and behavioral) and subjective (perception) is limited [Piper et al., 1987].

Subsequent studies have shown that fatigue as an objective state does not necessarily relate to the subjective feeling of fatigue [Aldasheva et al., 1992, Chalder et al., 1993, Khaengkhun et al., 2017]. The difference between the two lies in the measurement technique and can yield different results while applying it on the same population. Subjective fatigue considers solely the perspective of the individual on how fatigued one is, whereas objective fatigue captures visual indicators that would determine if one is fatigued.

Although fatigue can be measured both objectively and subjectively, there lies an inherent disadvantage in measuring fatigue objectively as it completely ignores the subjective feeling of fatigue that an individual undergoes [Phillips, 2015]. Moreover, measuring fatigue objectively limits the evaluation to a specific set of quantitative measurements. This motivates the choice to evaluate subjective fatigue and its underlying dimensions for this study.

2.1.3 Measurement of Subjective Fatigue

Efforts in measuring subjective fatigue has predominantly employed the use of self-reported scales [De Vries et al., 2004]. There is a need to tailor fatigue measurement to the environments in which fatigue is being studied [Aaronson et al., 1999]. This explains the many different scales that are found in fatigue literature. Instruments that are used to measure subjective fatigue can be split into unidimensional and multidimensional scales. Unidimensional scales as the name suggests, is designed to evaluate only one aspect of fatigue. Multidimensional scales on the other hand evaluate subjective fatigue from multiple perspectives. Multidimensional scales becomes useful for comparing profiles and gives us a more refined understanding about the underlying factors that lead to fatigue. Previous work

has targeted 2 areas of research; general workforce and clinical patients ([Aaronson et al., 1999]. Most studies are targeted towards measuring fatigue in clinical patients rather than the general workforce [De Vries et al., 2004].

Some of the widely used scales in the field of fatigue are "The Chadler Fatigue Scale", "Checklist Individual Strength(CIS-20)", "Cognitive Failures Questionnaire", "Wood Mental Fatigue Inventory", "Borg's category ratio(CR-10)", "Samn-Perelli Fatigue scale(SPFS)", "Swedish Occupational fatigue inventory(SOFI)" and "Multidimensional Fatigue Inventory"

The "Chalder Fatigue Scale" developed by Chalder et al. [1993] is a unidimensional self-administered 10-item fatigue scale used to differentiate between people who have been diagnosed with Chronic Fatigue Syndrome and those that are not. Chronic Fatigue Syndrome (CFS) is present in an individual if one displays persistent, relapsing, debilitating fatigue or those easily fatigued with no previous history of similar symptoms that does not resolve with bed rest and that is severe enough to reduce ones average daily activity below 50% for at least 6 months. The Chadler Fatigue Scale was originally used for measuring CFS in clinical population, but it is now used to measure the severity of fatigue.

The "Checklist Individual Strength" is a multi-dimensional self-administered 20 item checklist fatigue scale capable of measuring both physical and mental fatigue. This was originally constructed to assess chronic fatigue clinically. It is designed to measure several aspects of fatigue consisting of four dimensions: the subjective experience of fatigue, reduction in motivation, reduction in activity, and reduction in concentration. Originally, the validity of this 20-item questionnaire was tested adequately among clinical population who have been diagnosed with CFS. A further study was conducted to test the validity of the questionnaire in the working population by comparing Chalder Fatigue Scale with other scales of similar intensity [Dittner and Chalder, 2003].

The "Cognitive Failures Questionnaire" is a 25-item unidimensional scale that is aimed at measuring fatigue caused by mental strain. It evaluates cognitive failures such as "Forgetfulness", Distractibility" and "False Triggering". This survey used a 5-point scale (0-4). The survey is designed to assess the frequency with which people experience cognitive failures such as absent mindedness, perception slips and error, gaps in memory and loss of motor functioning [Wallace, 2004].

The "Swedish Occupational Fatigue Inventory" is a 25-item multidimensional scale. Jackson [2015] represents the fatigue scale as a short survey quantifying both physical and mental weakness. The items ask about sensations and functionality, and each of the 11 elements is answered on a 4-point scale ranging from the asymptomatic to extreme symptomologies. These symptomologies such as 'better than usual,' 'no worse than usual,' 'worse than usual' and 'much worse than usual'. Using the Likert scoring method, the respondent's global score can provide insights into both physical and psychological fatigue.

The above listed fatigue assessment scales were constructed in an attempt to measure subjective fatigue. These subjective fatigue and its measurement techniques provide insight into looking at a comparable state called burnout. This is vital in establishing our research gap which is further discussed in the sections to follow.

2.2 Burnout

Maslach [1998] defined burnout as "prolonged responses to chronic inter-personal stressors on the job". Maslach [1998] further explained burnout based on three dimensions: 'emotional exhaustion, 'depersonalization', and 'diminished personal accomplishment'. In a further study Maslach and Leiter [1997] designed the Maslach Burnout Inventory (MBI) Maslach et al. [1986] aimed at measuring levels of burnout.

Burnout was widely conceptualized in the early 1990s that burnout was prevalent and targeted only towards teachers, nurses, social workers and healthcare professionals [Kim et al., 2009]. The MBI [Maslach et al., 1986] when applied to other population targets some factors did not correlate to burnout. Evans and Fischer [1993] applied the MBI [Maslach et al., 1986] to a population teachers and company workers. the difference between factor analysis that three factors were present in the former sample (teachers) but depersonalization didn't appear in the latter sample (company workers). This led [Maslach et al., 1986] prompted a change in the scale to make it suitable for a more general application.

For the scale to be applied on a wider range of jobs, Schaufeli [1996] developed an extension of the MBI survey and called it the MBI-General Survey (MBI-GS). This survey replaces the three original factors (emotional exhaustion, depersonalization, and diminished

personal accomplishment) with three new burnout dimensions: 'exhaustion', 'cynicism', and 'reduced professional efficacy'. Exhaustion refers to fatigue or lack of energy to perform tasks, cynicism refers to losing interest and distancing oneself from ones job, and professional efficacy refers to low productivity, lack of accomplishment [Schaufeli et al., 2001]. Another construct 'employee engagement', is often discussed and examined alongside burnout in literature. The factors that constitute burnout are the exact opposite of the factors that characterize employee engagement.

2.3 Employee Engagement

Work engagement is a relatively new concept in organizational psychology which was initially introduced in the early 1990's. Kahn [1990] defined 'work engagement' as "the harnessing of organizational members themselves to their work roles; in engagement; people employ and express themselves physically, cognitively, and emotionally during role performances". The cognitive component refers to the employee's trust and belief in the organization, leadership and the working environment. The emotional dimension describes the employee's perception of their leadership and the organizational values. This physical dimension outlines the employee's ability to take on the work and responsibilities given.

Kahn [1990] describes engagement as a physiological and psychological state which involves the employee being physiologically and psychologically present while performing his role in the organization. From a pure psychological perspective Kahn [1990] theorized that engagement or disengagement of an individual depended on three conditions : 'meaningfulness', 'safety', and 'availability'. Building on his work, May et al. [2004] attempted to examine the determinants and mediating effects of 'meaningfulness', 'safety' and 'availability' on work engagement. As the only empirical study to test Kahn [1990]'s model, May et al. [2004] found that all the three physiological states were strongly related to engagement. further May et al. [2004] also found that job enrichment and role fit had a positive impact on meaningfulness.

Various studies have subsequently attempted tried to present a working definition of work engagement. Nelson and Simmons [2003] suggests that work engagement is displaying

positive attitude and emotions towards their organization, people who take personal meaning out of their work, who think that they are capable of managing their workload and be confident about their future in continuing to work. Rothbard [2001] suggests that employee engagement is characterized by two psychological components: 'attention' and 'absorption'. Attention is related to the "cognitive availability and the amount of time one spends thinking about a role" while absorption means "being engrossed in a role and refers to the intensity of one's focus on a role". A widely accepted and used definition of engagement is formulated by Schaufeli and Bakker [2004]. They defined engagement as "a positive fulfilling work-related state of mind that is characterized by 'vigor', 'dedication' and 'absorption'." Schaufeli et al. [2006] goes onto state that vigor isn't a specific state or momentary, but it is a more persistent cognitive state that is not focused on any particular object, event, individual or behavior.

The impact of employee engagement on the organization can have a positive and a negative outcome. Harter et al. [2002] state that employee engagement can positively impact key business metrics like customer satisfaction, customer loyalty, productivity and profitability. On the other hand, employee engagement can negatively affect turnover [Harter et al., 2002]. One of the most widely accepted and used scales to measure work engagement is the Utrecht Work Engagement Scale (UWES) developed by Schaufeli et al. [2002]. The Utrecht Work Engagement Scale (UWES) developed by Schaufeli et al. [2002] is a short questionnaire consisting of 17 items collectively measuring the three underlying factors of engagement. 'vigor' contained six items, 'dedication' contained five items and 'absorption' contained 6 items. Initially the scale was developed with a total of 24 items, but upon a factor analysis the number of items was reduced to 17. The most recent version of the UWES (UWES – 9) has been developed with a total of three items per factor.

A study conducted by Seppälä et al. [2009] tested the factor and construct validity comparing both the UWES-17 and UWES-9 which showed that the both the scales supported the three-factor structure of engagement. The UWES-9 (shortened version) showed better construct validity over time. The widely accepted and validated UWES-9 scale has been chosen as the tool to measure engagement in this study.

2.4 Fatigue and Burnout

Fatigue and burnout are similar concepts, but the former is a broader construct while playing a central role in characterizing the latter in general population [Schaufeli and Enzmann, 1998]. The study conducted by Leone et al. [2007] illustrated the overlap between pure fatigue and pure burnout cases. This study presented cases that validated these concepts based on similar demographic factors. There was a difference between the two among the severe health and work related factors. The pure fatigue group tended to do worse than the pure burnout group. Burnout is presumed to occur only inside work related context [Schaufeli and Taris, 2005]. This is evidence that fatigue and burnout overlap each other. Another difference between fatigue and burnout is that they are studied in different timelines as burnout occurs over longer periods of time whereas fatigue occurs in a comparatively lesser time.

2.5 Burnout and Engagement

The relationship between burnout and engagement has been long debated in literature. Maslach et al. [2001] perceived engagement as a positive antithesis of burnout. In other words, engagement which is characterized by energy, involvement and high efficacy is the exact opposite of burnout which is characterized by exhaustion, cynicism and decreased efficacy. Maslach et al. [2001] further described that both burnout and engagement lie in a continuum and they are situated in the opposite ends of the spectrum. Furthermore, they concluded that at any given point in time, an individual is bound to lie somewhere along the continuum [Maslach et al., 2001].

Though Schaufeli et al. [2002] had a different argument. They conducted confirmatory factor analysis on both the engagement and burnout models to determine that the two factors can act independently and not necessarily impact each other. But, [Schaufeli et al., 2002] suggested that 'vigor' and 'dedication' are the two opposite factors of burnout (emotional exhaustion and cynicism) with absorption as the third factor being identified. So, with these definitive set of factors, Schaufeli and Bakker [2003] developed and tested

the Utrecht Engagement Scale (UWES) which included the three factors 'vigor', 'dedication' and 'absorption'.

Although the relationship between burnout and engagement has been established with multiple studies, subjective fatigue's relationship with employee work engagement has not been studied so far in literature.

2.6 Research Gap

There is evidence in the form of literature to support the relationship between burnout and engagement. Although burnout is a subset of fatigue in general, there is no evidence in literature from previous work that establishes the relationship between subjective fatigue and work engagement. Fatigue in our study is subjective, which only accounts for the employee's perception of the effects. Likewise, the employee work engagement levels are measured with the help of a pre-validated and widely used survey. The primary aim of this study is to determine if high subjective fatigue level in individuals have a detrimental impact on their work engagement level.

Chapter 3

Methodology

3.1 Introduction

This chapter outlines the research methodology followed in this study which includes the research design, survey development, data collection, model development, testing the hypothesis and statistical analysis. The research design explains the approach used in this study. Next, the survey questionnaire was developed based on previous literature, modified and tested for consistency and validated based on pilot tests. Post validation, the final set of data was collected for further analysis. Fourth, the model was developed, followed by testing of the model with the measurement model and structural model analysis. Fifth, the data collected is analyzed with the help of the Structural Equation Modelling (SEM). In addition, the hypothesis was proposed and subsequently tested. Lastly, the results, findings and their implications are presented and discussed in the next chapter. The complete research structure is explained in Figure 3.1

3.2 Research Design

This study used a cross-sectional study to examine the correlation and causality between employee work engagement and subjective fatigue in the same population. Though literature suggests that a lot of studies measuring fatigue in working population was done on a longitudinal basis, our study was time constrained and hence a cross-sectional approach

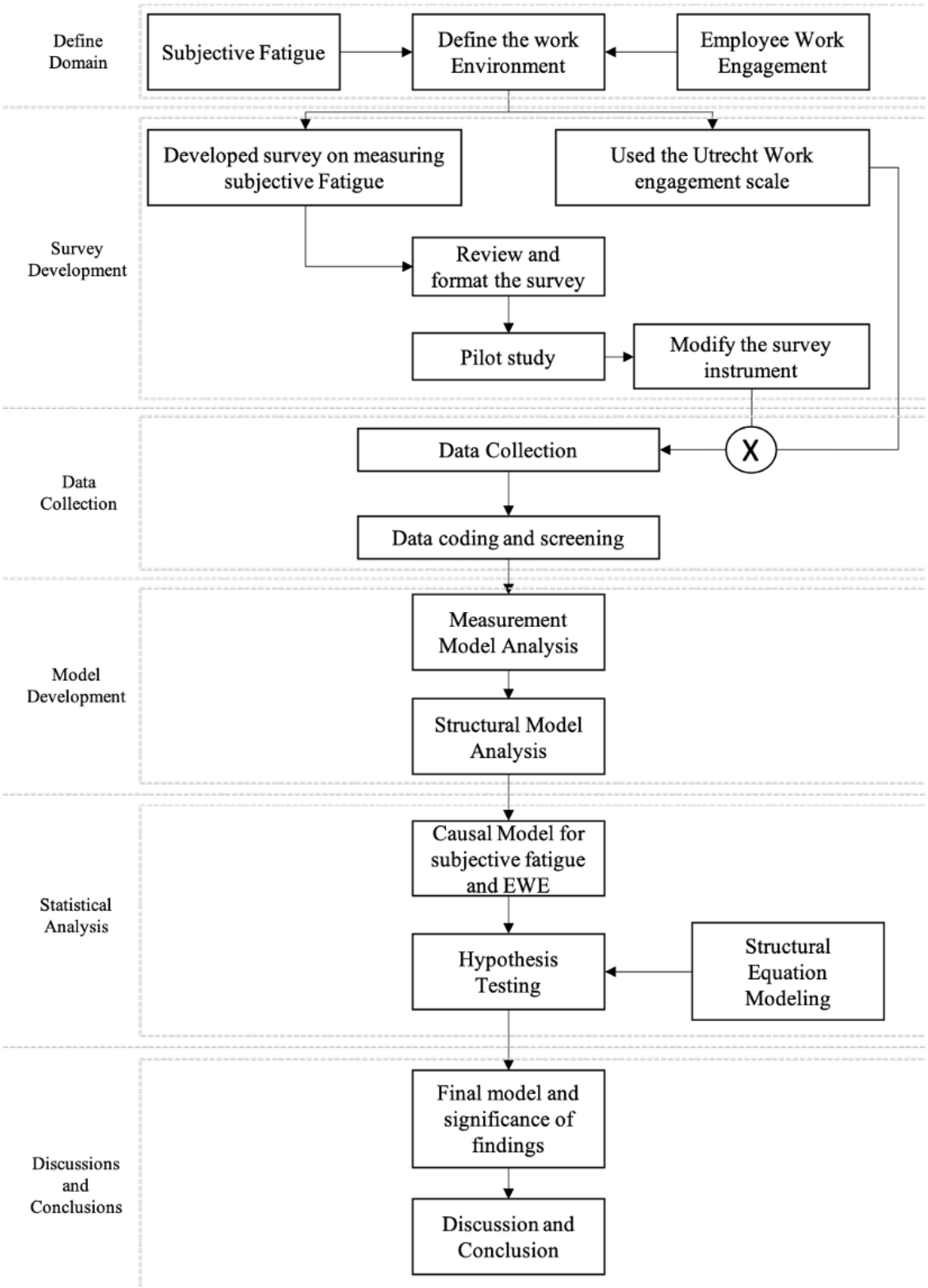

Figure 3.1: Structure of Research.

was adopted to collect data. The data was collected from a manufacturing company in the East Tennessee area. Though a cross-sectional study may not have the robustness of a longitudinal study, it allows a large scale data collection and analysis in relatively less time and is also cost efficient.

3.3 Phase 1: Domain

The domain of this research comprises of two constructs, namely 'Subjective Fatigue' and 'Employee Work Engagement'. Both these variables are subjective in nature and are studied under specific work conditions. The work environment comprises of individuals who perform tasks that are demanding like constantly lifting heavy materials, performing repetitive tasks, constant bodily movement (walking, climbing, standing etc.) that can induce stress and fatigue in muscles.

3.4 Phase 2: Survey Development

This study looks into 2 major constructs, fatigue and employee work engagement. Each of these two constructs were measured by using two individual survey instruments. As cited in the previous chapters, measuring fatigue has always been landscape specific by development of scenario and population driven questions [Aaronson et al., 1999]. A questionnaire was developed with factors that cause subjective fatigue in a heavy workload manufacturing environment.

3.4.1 Fatigue

The survey instrument aimed at measuring subjective fatigue and its factors was derived based of previous literature as described in Chapter 2. The survey instrument had 16 Likert scale questions measuring a total of 5 factors. The factors as described in Chapter 2, considered for this survey are 'physical exertion', 'physical discomfort', 'lack of motivation', 'environmental conditions', 'sleepiness', 'tiredness', 'lack of energy' and 'long work hours'. The factors and the expression were selected keeping in mind the environment to which they

applied to and through systematic interviews of people being asked to describe how they perceive fatigue in their job. These factors in combination measured the overall dependent (endogenous) variable, 'subjective fatigue'. The questions had a 7 point Likert scale ranging from 'never' to 'always' as the two extremes (1 & 7). The survey instrument has been included in the Appendix for reference. A summary of the subjective fatigue questionnaire is shown in Table 3.1.

3.4.2 Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) is a statistical technique which is used to measure the correlations between two independent and dependent factors. The purpose of conducting an EFA is to reduce the number of variables from a given structure. EFA checks the underlying correlation between a dependent and independent variable and whether the factors are indeed a linear combination of the observed variable. For this study, the Kaiser-Meyer-Olkin (SMO) test was used to check the structural consistency of the dependent and independent variables. A value in the range of 0.8 and 1 is considered to be ideal, between 0.6 and 0.8 it is considered acceptable and anything below 0.6 suggests that the variable is unfit for the model.

3.4.3 Employee Work Engagement

Measuring work engagement was accomplished with the help of a validated and widely administered questionnaire for our study. The Utrecht Work Engagement Scale (UWES) developed by Schaufeli and Bakker [2004] consists of 17 Likert scale questions measuring 3 factors. They are Vigor, Dedication and Absorption was used as the instrument to measure Employee Work Engagement (EWE). The authors define the three factors as the following:

Vigor – "It is characterized by high levels of energy and mental resilience while working, the willingness to invest effort in ones work, and persistence even in the face of difficulties." Dedication – "It refers to being strongly involved in ones work and experiencing a sense of significance, enthusiasm, inspiration, pride, and challenge." Absorption – "It is characterized by being fully concentrated and happily engrossed in ones work, whereby time passes quickly, and one has difficulties with detaching oneself from work."

Table 3.1: Survey Summary - Subjective Fatigue

Factors	**Number of questions**
Physical Exertion	5
Physical Discomfort	5
Lack of Motivation	4
Environmental Conditions	2

This questionnaire is also measured based on a 7 point Likert scale ranging from 'never' to 'always' as the two extremes (0-6). To make the Likert scale points consistent with the fatigue questionnaire, the scale shifted by a value of 1 to match with its new grading system being from 1 to 7. The expressions of the corresponding points remained the same. The survey instrument has been included in the Appendix for reference. A summary of the Utrecht Work Engagement survey is shown in Table 3.2.

3.4.4 Ethical Considerations

The survey instrument and the data collection methods were reviewed and approved by the Institutional Review Board (IRB) at the University of Tennessee, Knoxville. Guidelines and ethics outlined by the IRB was followed. Prior to handing out the surveys, the individuals were informed that participating in the survey was voluntary and that their individual responses would be kept confidential if they were willing to participate. They were also informed that the employee and employer rights will in no manner be violated. Furthermore, they were told that at any time while answering the survey, they may withdraw, decline to answer any of the questions if they felt uncomfortable in doing so. In order to maintain confidentiality of the participant's responses, no personal details were asked as a part of the survey and were only asked to fill demographic questions (age, sex). Following the data collection, the results were clustered and stored as aggregated data to avoid any identification. The IRB approval letter has been attached in the Appendix for reference.

3.5 Phase 3: Data Collection

3.5.1 Sample Population

It is vital that the sample population for any study be clearly defined, as selecting the target population incorrectly can have grave implications on the study like the data losing its value and the results not reflecting the intended purpose of the study. A target population can be defined as the set of individuals or a group who can answer the survey and results directly apply to that chosen group [Kitchenham and Pfleeger, 2002]. The target population has to

Table 3.2: Survey Summary - Employee Work Engagement

Factors	**Number of questions**
Vigor	3
Dedication	3
Absorption	3

represent a finite member of their population. The next step would be to determine a sample population, or in other words a subset of the target population. For this study, our sample population included manufacturing workers from the state of Tennessee. According to a 2018 report from the Tennessee Department of Labor and Workforce Development, 11.32% of the total workforce are employed in the manufacturing sector in Tennessee. This justifies the sample size and its target population used in this study Also, the researchers ability to access these manufacturing sites is significant which further justifies the sample population chosen for this study.

3.5.2 Sample Size

Any survey instrument to be successful in its application, the right sample size must be determined. But, deciding the sample size for a Structural Equation Modelling (SEM) based approach remains an ambiguous problem and a definite standard for the required sample size is yet to be determined despite an increase in the number of SEM based approaches lately. Having said that, SEM based approaches have adopted a flexible approach when deciding on the sample size requirements. This is due to the PLS-SEM algorithm which does not compute all relationships in the structure simultaneously and instead uses ordinary least squares (OLS) regression technique to compute the model's partial regression relationships. This study applies an often cited [Barclay et al., 1995, Chin and Newsted, 1999, Kahai and Cooper, 2003] and commonly used '10 responses per indicator/variable that is used to measure a single construct'. In other words, it can be explained as 10 times the number of structural paths that is directed towards a particular construct. In the presented conceptual model in this chapter, it can be seen that the model has two constructs: 'Fatigue' (F) and 'Employee Work Engagement' (EWE). The F construct has a total of four indicators and EWE construct has three indicators. Thus, a total of 7 indicators in combination explain the F and EWE constructs. According to the above mentioned '10 times rule', 7 x 10 = 70 represents the sample size that is deemed adequate for the estimation of this SEM model.

3.5.3 Data Coding

The survey was conducted with hard copies handed out to the respondents and the responses were required to be tabulated and screened to increase its usefulness. The steps involved in the screening process have been described in the next section (Section 3.5.4). Table 3.3 summarizes the data coding and enables screening and analysis of the data.

3.5.4 Data Screening

Screening the data is a vital and necessary process that helps to have a clean version of the data ready for performing various statistical analysis. The data is checked for multiple issues that may arise in an unchecked data dump. Firstly, the data is checked for any missing responses which usually arises due to the respondent failing to answer one or more question(s). Such anomalies can have a detrimental effect on the conclusions made if the researcher fails to address them. For this study, the researcher made efforts to ensure that the respondents answered all the questions asked on the survey.

3.6 Phase 4: Building the Model

3.6.1 Theoretical Background

In aims to analyze the effect of subjective fatigue on employee work engagement (EWE), this study attempts to address this key question: does high levels of subjective fatigue cause low levels of EWE for employees working in a manufacturing environment. Hence this study employs one model: subjective fatigue and EWE causal model.

3.6.2 Notation

Before constructing the structural model for our study, the mathematical notation of the variables have to be defined for the variables, factor loadings, regression weights and error terms. The term Y represents the observed endogenous variable (dependent) and the term X represents the observed exogenous variable (dependent). There are no mediating

Table 3.3: Data Summary

Factors	**Item Sequence**	**Answer Type**	**Points**
Physical Exertion	1-5	Likert	7
Lack of Motivation	6-9	Likert	7
Physical Discomfort	11-14	Likert	7
Environmental Conditions	15,16	Likert	7
Vigor	17-19	Likert	7
Dedication	20-22	Likert	7
Absorption	23-25	Likert	7
AB	1.21	Likert	7
EWE	1.039	Likert	7

variables/factors in our study and hence we did not define the same. The variable λ_{imn} is the factor loading between the observed and latent variable, is the regression coefficient between the exogenous and endogenous variable. Variables α and ε represent the error terms for the observed and latent variables respectively as shown in Figure 3.2.

3.6.3 Measurement Model Analysis

Although the questionnaire was subjected to a pilot test, it is significant to test the survey for reliability and validity before it is applied on a large group of participants. Below are the steps that were followed in testing the measurement model.

Instrument Reliability (Internal)

Reliability is the degree of consistency shown by the scale when applied multiple times under identical conditions. A number of reliability estimation methods have been developed including Cronbach's Alpha [Cronbach, 1951], ordinal alpha [Zumbo et al., 2007] test-retest reliability, Raykov's rho [Raykov and Marcoulides, 2011] and McDonald's Omega [McDonald, 2013]. Among these, Cronbach alpha and test-rest reliability are the most commonly used methods to assess reliability of scales [Lattin et al., 2003].

Cronbach's alpha coefficient is widely believed to be a reliable measure of the internal consistency of instruments. The math behind Cronbach's alpha is as follows:

$$\alpha_{standardized} = \frac{K \cdot \bar{r}}{(1 + (K-1) \cdot \bar{r})} \tag{3.1}$$

where K is the number of variables and is the average correlation among all the pairs of variables. Cronbach's alpha assess the degree to which the set of items in the scale vary, relative to their sum score [Cronbach, 1951, DeVellis, 2016]. The value of the Cronbach's alpha coefficient varies between 0 and 1 and a high value (closer to 1) means that the instrument is highly reliable. A score of 0.7 is widely regarded as an acceptable threshold value for reliability, although a score ranging from 0.8 to 0.95 is needed to maintain the psychometric quality of the scales [Nunnally, 1994].

Type	Notation	Meaning
Variable	η_{Xm}	Latent variable for 'X_{mn}' observed variables.
	η_{Ym}	Latent variable for 'Y_{mn}' observed variables.
	X_{mn}	Endogenous (dependent) 'n' observed variables for latent variable 'm'.
	Y_{mn}	Exogenous (indeoendent) 'n' observed variables for latent variable 'm'.
Path coefficient	γ_{YmXn}	Regression path between exogenous latent variable 'X_n' and endogenous variable 'Y_m'.
Factor Loading	λ_{imn}	Factor loading for path 'mn' between the latent variable and observed variable.
Error Term	α_{imn}	Error term for observed variable 'i', where i = X,Y.
	ε_{in}	Error term for latent variable 'i', where i = X,Y.

Figure 3.2: Structural Equation Model Notation

Validity

Validity can be explained as the extent to which an instrument measures the construct or the latent variables it was developed to evaluate. For this research, the validity of the instrument is assessed through content, face, convergent and discriminant validity.

The first step in validating the instrument is to check for 'convergent validity' which means "adequacy with which a measure assesses the domain of interest" [Hinkin, 1995]. In addition to that, content validity also looks at context relevance and content representations [Church and Waclawski, 2007]. Guion [1977] outlines five conditions that a researcher must follow while testing for content validity of an instrument. They are listed as follows: a) The content domain must be rooted in behavior with a generally accepted meaning. b) The content domain must be defined unambiguously. c) The content domain must be relevant to the purpose of measurement. d) Qualified judges must agree that the domain has been adequately sampled. e) The response content must be reliably observed and evaluated. The content validity was evaluated using the above steps and also the relevance of fit between the factors chosen from literature.

'Face validity' is a component of content validity or in other words, the instrument has to be checked first for its content validity before evaluating its face validity. Face validity can be defined as the "degree to which the respondents or participants of the study, find the items of the instrument appropriate to the targeted construct and its assessment objectives" [Haynes et al., 1995]. This is achieved by interviewing the respondents as to whether the chosen construct and its items are relevant to them.

Both convergent and discriminant validity classify under a post-administration validity examination known as 'construct validity'. It is referred as the "extent to which an instrument assesses a construct under consideration and is associated with evidence that measures other constructs in that domain and measures specific real-world criteria" [Raykov and Marcoulides, 2011]. Convergent validity is the extent to which, two different instruments measuring the same construct yield similar results. In other words, it the "degree to which scores on a studied instrument are related to measures of other constructs that can be expected on theoretical grounds to be close to the one tapped into by this instrument"

[Campbell and Fiske, 1959, Churchill Jr, 1979, Raykov and Marcoulides, 2011]. Thus, a comparable instrument is expected to have a moderate to high correlation with the instrument under study. In this research, the criterion for the convergent validity was considered acceptable at values 0.50 or higher.

Discriminant validity is the novelty of the survey instrument and not simply a reflection of a preexisting construct [Campbell and Fiske, 1959]. Raykov and Marcoulides [2011] defines it as the "degree to which scores on a studied instrument are differentiated from behavioral manifestations of other constructs, which on theoretical grounds can be expected not to be related to the construct underlying the instrument under investigation". To prove this, the study uses confirmatory factor analysis to highlight the discriminant validity among subjective fatigue and its measurements.

3.7 Phase 5: Structural Model Analysis

Building the final model can be considered a two stage process. The model has two parts to it: Structural Model and the Measurement Model. Figure 3.3 clearly outlines both parts of the structural equation model. Once the measurement model is examined, the structural model's capabilities and the relationship between the constructs is evaluated with the help of certain statistical procedures. The first step would be to check for any collinearity issues with the structural models and its variables because the estimation of path coefficients is based on OLS regression of every endogenous latent variables with its corresponding constructs. The significance of path coefficients, predictive relevance Q^2, the effect size are the key steps that are to be followed while analyzing the structural model in PLS-SEM and the outcomes of these analysis would determine the causality between Subjective Fatigue and Employee work engagement.

3.8 Hypothesis Testing

The goal of this study was to build a structural model that examines the causal relationship between two independent latent variables, subjective fatigue and employee work engagement.

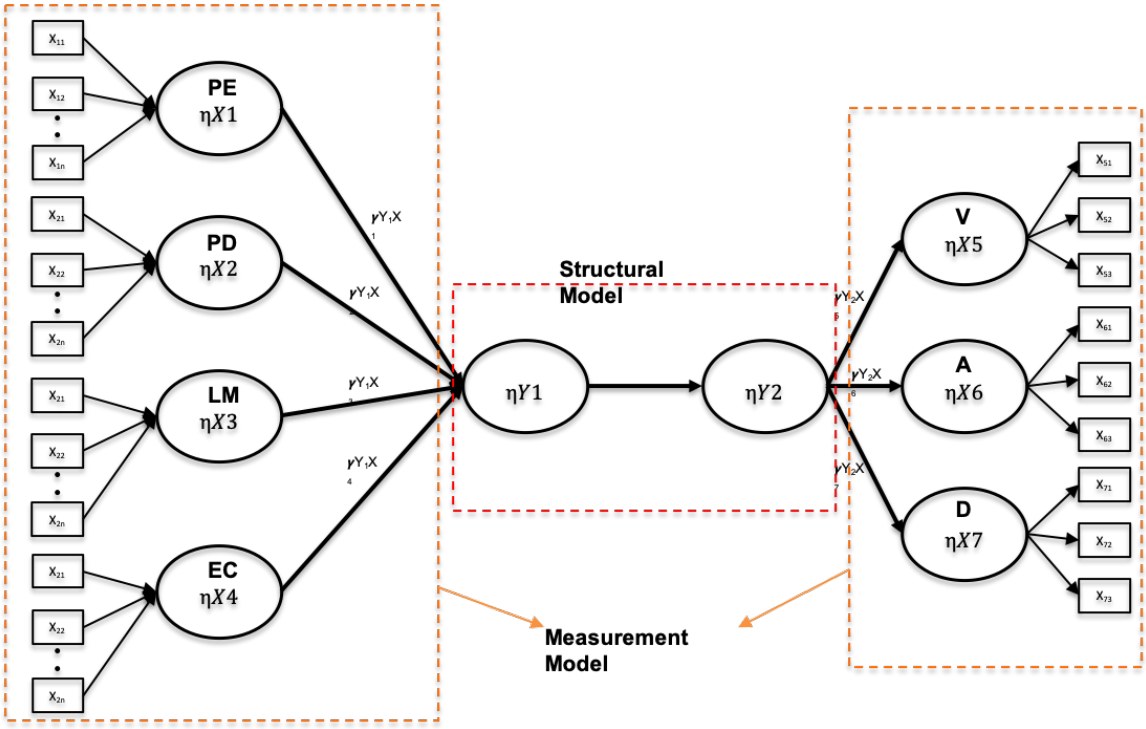

Figure 3.3: Structural Equation Model

The underlying causal factors or dependent variables of both constructs are subjected to a correlation analysis as well. The hypothesis are listed as follows:

- Hypothesis (H1): Subjective fatigue has a significant negative influence on employee work engagement.

3.9 Summary

This chapter discussed in detail the steps that were performed to investigate the factors impacting subjective fatigue. The survey instrument used in this study was derived based on previous literature which is discussed in Chapter 2. The survey was reviewed and approved by the IRB at the University of Tennessee, Knoxville making the instrument ethically viable and administrable. A pilot study was conducted to eliminate any feasibility issues, thus making the survey more effective. The survey instrument was handed out as hard copies to the participants from a manufacturing company in Tennessee. The data collected was then subjected to data coding and screening to help improve the usefulness and remove data anomalies. In the model development section, the measurement model and structural equation modeling was explained. The steps involved checking for consistency reliability and validity using the measurement model and with the structural model, testing for collinearity, path coefficient and predictive relevance. Testing of hypothesis was done on the fatigue and employee work engagement for causality.

Chapter 4

Research Findings

4.1 Introduction

This chapter presents the analysis of the data based on the case study. The first section of this chapter summarizes the demographic assessment, data cleaning, and results. This is followed by the analysis and evaluation of the measurement and structural model, and hypothesis testing.

4.2 Descriptive Statistics

The target population of the case study comprises groups from two manufacturing facilities located in the state of Tennessee. The names of the companies are kept confidential to adhere to the ethical considerations as presented in Section 3.4.4.

A summary of the demographics that were collected during the survey is presented in Table 4.1. The data was collected on a single day , with a hard copy of the questionnaire presented to each of the volunteering participants. With the help of the production manager and the supervisor, the employees were called in batches of 10 to participate in the study. This was done to ensure that the production at the facility continued uninterrupted.

Table 4.1: Response frequency (Company 1 & Company 2)

			Location		Total
			Company 1	Company 2	
Consent	Consent granted	Count	96	21	117
		Percentage	77.4%	100%	80.6%
	Consent denied	Count	28	0	28
		Percentage	22.5%	0%	19.3%

4.2.1 Data screening

The data collected from the survey was screened to check for any missing values and normality. The normality of the data was analyzed by checking for skewness or kurtosis using IBM SPSS25. Values of skewness between -3 and +3, and kurtosis between -10 and +10 [Geroge and Mallery, 2003] are acceptable. The results (Figure 4.1) showed that the skewness and kurtosis of the data are well within the acceptable range. Skewness lied between -0.057 and 0.645 and the kurtosis lied between -1.014 and 0.35. This meant that the data was not left or right skewed and the data was not too peaked at the center. Additionally, the data had no missing values and no outliers since Likert scale was used. This allowed the data to be deemed fit for analysis.

4.2.2 Data summary

A demographic representation of the screened data is presented below in Table 4.2, with the age and sex as the only demographics.

Out of the 145 questionnaires distributed, 117 responses (80.6%) were returned and all of them were useful and fit for analysis (Section 4.2.1). As shown in Table 4.2, 70.9% of the respondents was male and 29% were female. Age range of the respondents are from 29-58 and the highest cluster was found in the 29-39 age group (33.3%) followed by the 39-49 age group (37%). An evenly spread distribution was found among all age groups.

4.3 Evaluation of the Measurement Model (Outer Model)

The framework presented in Section 3.6 shows the proposed model of this study. The model contains two second order variables for Subjective Fatigue and Employee Work Engagement, consisting of 4 and 3 first order observed variables respectively. The Utrecht Work Engagement scale developed by Schaufeli et al. [2006] is a validated questionnaire used in this research and will be considered for the analysis. The goal of this section is to analyze the measurement model (outer model) for its reliability and validity.

	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Q 1	117	-.027	.224	-.549	.444
Q 2	117	.328	.224	-.465	.444
Q 3	117	.427	.224	.023	.444
Q 4	117	-.033	.224	-.460	.444
Q 5	117	.475	.224	.039	.444
Q 6	117	.510	.224	.350	.444
Q 7	117	.273	.224	-.380	.444
Q 8	117	.472	.224	-.110	.444
Q 9	117	.354	.224	.044	.444
Q 10	117	.304	.224	-.389	.444
Q 11	117	.645	.224	.215	.444
Q 12	117	.253	.224	-.184	.444
Q 13	117	.269	.224	-.669	.444
Q 14	117	.245	.224	-.546	.444
Q 15	117	.277	.224	-.295	.444
Q 16	117	.000	.224	-.648	.444
A 1	117	.539	.224	-.221	.444
A 2	117	.311	.224	-.452	.444
A 3	117	.161	.224	-.547	.444
A 4	117	-.057	.224	-.762	.444
A 5	117	.320	.224	-.479	.444
A 6	117	.140	.224	-.715	.444
A 7	117	.186	.224	-.717	.444
A 8	117	.095	.224	-.512	.444
A 9	117	.080	.224	-.790	.444
A 10	117	.295	.224	-.631	.444
A 11	117	.271	.224	-.807	.444
A 12	117	.305	.224	-.666	.444
A 13	117	.353	.224	-.724	.444
A 14	117	.203	.224	-.625	.444
A 15	117	.257	.224	-.711	.444
A 16	117	.064	.224	-1.014	.444
A 17	117	.192	.224	-.630	.444
Valid N (listwise)	117				

Figure 4.1: Skewness and Kurtosis.

Table 4.2: Demographics

Demographic	**Variable**	**Frequency**	**Percent**	**Cumulative percent**
Gender	Male	83	70.9	70.9
	Female	34	29	100
Age	20-29	24	20.5	20.5
	29-39	39	33.3	53.8
	39-49	37	31.6	85.4
	49-59	17	14.5	100

4.3.1 Reliability test

The reliability test is done to ensure the internal consistency of the measuring instrument. The items (questions) were structured based on a 7 point Likert scale ranging from "never" (1) to "always" (7) which enabled the participants to respond favorably or unfavorably towards the given constructs. Any item with reliability less than 0.70 is generally considered to be unreliable and unfit to use. The collected data was analyzed using IBM SPSS25 to check for the Cronbach's alpha of each factor.

The 7 variables (physical exertion, physical discomfort, lack of motivation, environmental conditions, vigor, dedication and absorption) were analyzed individually for internal consistency. The results of the analysis is shown in Figure 4.2. All factors excluding Physical Exertion (PE) displayed satisfactory internal reliability. Upon, removing an underlying question from 'PE', the Cronbach's alpha proved to be satisfactory. The questionnaire displayed a good internal reliability.

4.3.2 Validity Analysis

Validity analysis is done to check for the suitability of the measurement, defined as the degree to which an instrument measures what it sets out to measure [Gay et al., 1992]. The validity of the instrument was analyzed using the face validity, content validity, convergent validity and discriminant validity.

To test the face and content validity of the questionnaire, a comprehensive literature review was performed with the chosen items measuring the construct of subjective fatigue. The Utrecht Work Engagement scale is a pre-validated instrument that is proven to measure the Employee Work Engagement construct. Comments and feedback about the instrument was gathered from the faculty members of the Department of the Industrial Systems and Engineering, and a few participants from the pilot study. This enabled to make modifications to fulfill the face and content validity requirements.

Discriminant validity analysis helps in demonstrating that two constructs which are theoretically uncorrelated are not found to be correlated. This was assessed using the Fornell-Larcker analysis which proposes comparing the square roots of the Average Variance

- Physical Exertion — Cronbach's α is 0.578, less than 0.7, delete 1 item, revised value is 0.732
- Lack of motivation — Cronbach's α is 0.748, greater than 0.7
- Physical Discomfort — Cronbach's α is 0.823, greater than 0.7
- Environmental Conditions — Cronbach's α is 0.724, greater than 0.7
- Vigor — Cronbach's α is 0.850, greater than 0.7
- Absorption — Cronbach's α is 0.761, greater than 0.7
- Dedication — Cronbach's α is 0.821, greater than 0.7

Figure 4.2: Cronbach's Alpha.

Extracted (AVE) for the two latent variables and their inter-correlations. The discriminant validity table is presented in Table 4.3 shows adequate discriminant validity due to diagonal elements greater than any value in the row and column. This tells us that the individual constructs in model are not correlated to each other but distinct in what they are measuring.

4.4 Evaluation of the Structural Model (Inner Model)

The measurement model analysis have shown that the constructs of the model are valid and reliable, thus paving the way for evaluating the structural model. The evaluation criteria considered are the Coefficient of Determination R^2, collinearity assessment, path coefficients and predictive relevance Q^2 and finally testing the hypothesis.

4.4.1 Coefficient of determination of R^2

The coefficient of determination of R^2 is a measure of the squared correlation between the predicted values and the actual values of the construct. In other words, it determines how well the model fits the data. The R^2 value for 'Subjective Fatigue' (SF) and 'Employee Work Engagement' (EWE) are 0.994 and 0.542 respectively. This illustrates that the model fits the data and can handle the complexities of the model. Furthermore, it suggests that the data points of both 'SF' and 'EWE' are closely fitted to the regression line.

4.4.2 Collinearity Assessment

This is performed on the structural model using the Variance Inflation Factor (VIF). The SmartPLS results shown in Table 4.4 show that all VIF values are below the threshold value of 5. This indicates that the individual factors are not inter-correlated with the other factors. This allows us to proceed with the bootstrapping analysis to determine the causality between subjective fatigue and employee work engagement.

Table 4.3: Discriminant Validity

	AB	DE	EWE	EC	LM	PD	PE	SF	V
AB	0.478								
DE	0.286	0.5							
EWE	0.606	0.804	0.931						
EC	-0.232	-0.235	0.265	0.481					
LM	-0.08	-0.14	-0.099	0.285	0.539				
PD	-0.069	-0.086	-0.083	-0.03	0.351	0.818			
PE	-0.014	0.008	-0.057	0.158	0.23	0.247	0.734		
SF	-0.313	-0.256	-0.285	0.213	0.369	0.309	0.258	0.992	
V	0.332	0.127	0.461	-0.034	-0.002	-0.024	-0.11	-0.038	0.702

4.4.3 Path Coefficients

The path coefficients estimate the probable relationships among the constructs of the model. Their size and the sign (negative or positive) will determine the effect on the latent variables. The significance is determined by running a T-test. The model is run with 1000 bootstrapping samples. The results of the bootstrapping are presented in the subsequent sections.

4.5 Hypothesis Testing

In order to examine the relationship between subjective fatigue and employee work engagement, a correlation analysis was performed with SmartPLS. It enables the computation of correlations and the strength of the correlation between the variables. Our hypothesis as presented in Section 3.6 postulates that high subjective fatigue levels cause low employee engagement levels in employees working in a heavy manufacturing facility. The correlation between the two constructs is shown in Table 4.5. SF and EWE have a positive correlation of 0.737. This indicates that there is strong relationship between the two constructs. The results for the causal analysis is presented in the next section.

4.5.1 Hypothesis testing for Subjective Fatigue and Employee Work Engagement

The relationship between SF and EWE. is evaluated using a regression with the help of a bootstrapping analysis. Figure 4.3 presents the results of the sign, the direction of the path coefficient and the overall results of the hypothesis testing which is significant at $p < 0.05$.

The hypothesis H1 stated that fatigue levels of employees are a significant predictor of the employee work engagement levels of the same. Figure 4.3 shows that, the structural path coefficient value between the two individual constructs is 0.271 and the corresponding p-value is 0.348. Although the path coefficient value is significant, it cannot be accepted as the p value is not less than 0.05. This implies that there is no significant causation between SF and EWE. Thus, we can infer that SF is not a significant predictor of EWE. Although

Table 4.4: Collinearity Assessment

Variable	**VIF**
PE	1.351
LM	1.451
PD	1.459
EC	1.364
SF	1.039
V	1.235
DE	1.093
AB	1.21
EWE	1.039

Table 4.5: Correlation between Constructs

Variables	**Mean**	**S.D**	**EWE**
SF	-0.282	0.432	0.737

the previous section indicated a correlation, a unidirectional casual relationship is proven to be non-existent. On the other hand, the fact that there lies a correlation between the constructs provides insight into the relationship between the two variables. While we may have only studied a simple unidirectional causal relationship between the two, the existence of a correlation opens up the possibility to consider higher order variables which could have an impact on the causality.

Hypothesis	Proposed hypothesis relationship	Sign (+ or -)	Estimate results	P value	Results
H1	SF → EWE	+	0.271	0.348	Non-Significant

Figure 4.3: Results of SEM hypothesis testing for Subjective Fatigue

Chapter 5

Conclusions

5.1 Introduction

Fatigue among the working population has been a persistent problem that companies have to deal with today. Despite the surge in automation and companies adopting different automation techniques, people are still tasked to work in labor intensive environments. Fatigue not only impacts the individual on a personal level, but also companies bearing its effects when it comes to having a fatigued workforce. It includes increased workplace accidents, absenteeism, decreased productivity and all of this translates to a considerable loss in working hours and productivity, and finally the company's profits. Burnout, a condition similar to subjective fatigue is proven to be a positive antecedent to work engagement. In other words, high burnout levels at work can lead to low employee engagement levels. Subjective fatigue, which considers a comparatively broader range of factors associated with it, has a detrimental impact on an individual. Since burnout and subjective fatigue are closely linked, it was useful to examine the empirical relationship between Subjective Fatigue and Employee Work Engagement.

This study aimed to answer the following question:

Does high subjective fatigue levels in employees cause low work engagement levels among them?

The answer to this question is that subjective fatigue does not seem to have a significant effect on the engagement levels of employees. The causal relationship between the two variables did not prove to be significant.

5.2 Contributions

The results of the subjective fatigue model presents a comprehensive list of items and their respective factors that measure the levels of subjective fatigue of an individual employed in a heavy workload environment. The factors and their corresponding items were chosen from reviewed literature and modified to suit the environment under which fatigue is studied. The individual loadings of the factors onto the subjective fatigue variable is presented below.

Figure 5.1 demonstrates strong causalities between the four factors, Physical Discomfort (PD), Lack of Motivation (LM), Physical Exertion (PE), Environmental Conditions (EC), and Subjective Fatigue (SF). The 'subjective fatigue' framework provides a robust approach towards measuring subjective fatigue among individuals who work in heavy workload manufacturing environments. This research also explored models with the help of PLS-SEM approach and found that causality between two latent variables can be analyzed. Also, the PLS-SEM approach provides a unique yet, robust approach in building and validating causal models. In short, this research provides a systematic analysis in exploring the effect of subjective fatigue on employee work engagement.

5.3 Practical Implications

The primary goal of this research was to contribute to understanding the effect of subjective fatigue on employee work engagement. This research also provides manufacturing companies with a heavy workload environment to better evaluate the levels of subjective fatigue among their employees. Although, the results reflect that there is no causality between subjective fatigue and employee work engagement, the survey instruments chosen and developed for this survey would provide useful information for companies to better understand and deal with their disengaged fatigued workforce.

Factor loadings	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
EC -> SF	0.322	0.319	0.04	7.984	0*
LM -> SF	0.375	0.378	0.039	9.638	0*
PD -> SF	0.324	0.316	0.04	8.199	0*
PE -> SF	0.325	0.322	0.04	8.204	0*

**Significant at p<0.5*

Figure 5.1: Subjective Fatigue Factor Loadings

5.4 Limitations and Future Work

- Although the individual constructs are valid, a causal analysis failed to provide any significant results.
- The factors and expressions considered were work related and the model did not consider any external factors outside work that may affect both the constructs such as physical/mental health issues, family conflicts, financial constraints and many more.
- No mediating relationship between the two constructs was used to alter the model's behavior and see if a causality exists.
- Surveys involving humans tend to have bias in their responses towards certain questions even if they feel the opposite which can have a significant impact on the findings. A combination of both objectively and subjectively measuring fatigue can help reduce this bias.
- The effect of time on the individuals experiencing varying levels of SF and EWE can yield significant results in an attempt to explore a causality which can be done with the help of a longitudinal study.
- A larger sample size from multiple organizations that predominantly function under heavy workload conditions can yield better results in the causal model.

5.5 Conclusions

The study of fatigue has never been easy, validated by the literature showing undying debate over its definitions, impacts, dimensions and its constructs. This study aimed at developing a robust instrument that is capable of measuring subjective fatigue levels of employees operating in a heavy workload environment and was successful in doing so. Combined with the developed instrument and the Utrecht work engagement scale (UWES) developed by Schaufeli et al. [2006], this study built a causal model which examined the directional effects of subjective fatigue on employee work engagement levels. The results indicated that both

constructs were strongly correlated, but a causal relationship between the two was found to be non-existent. With the study limited to its resources available, it sets up a foundation for future studies that can look at obtaining a larger sample size, include mediating relationships, perform a longitudinal study and include more factors in the model to obtain better results.

Bibliography

L. S. Aaronson, C. S. Teel, V. Cassmeyer, G. B. Neuberger, L. Pallikkathayil, J. Pierce, A. N. Press, P. D. Williams, and A. Wingate. Defining and measuring fatigue. *Image: the journal of nursing scholarship*, 31(1):45–50, 1999. 14, 15, 23

E. Åhsberg, F. Garnberale, and A. Kjellberg. Perceived quality of fatigue during different occupational tasks development of a questionnaire. *International journal of industrial ergonomics*, 20(2):121–135, 1997. 3, 13

A. Aldasheva, T. Chernook, M. Y. Glushkova, and R. D. Kurmanalieva. Dependence of working capacity and fatigue on the nervous and mental state of workers doing long stints in the mountains. *Human Physiology*, 18(5):371–374, 1992. 14

D. Barclay, C. Higgins, and R. Thompson. *The partial least squares (PLS) approach to casual modeling: personal computer adoption ans use as an Illustration*. 1995. 28

R. F. Brown and N. S. Schutte. Direct and indirect relationships between emotional intelligence and subjective fatigue in university students. *Journal of Psychosomatic Research*, 60(6):585–593, 2006. 13

D. T. Campbell and D. W. Fiske. Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological bulletin*, 56(2):81, 1959. 34

D. B. Chaffin. Localized muscle fatigue—definition and measurement. *Journal of Occupational and Environmental Medicine*, 15(4):346–354, 1973. 1

T. Chalder, G. Berelowitz, T. Pawlikowska, L. Watts, S. Wessely, D. Wright, and E. Wallace. Development of a fatigue scale. *Journal of psychosomatic research*, 37(2):147–153, 1993. 14, 15

W. W. Chin and P. R. Newsted. Structural equation modeling analysis with small samples using partial least squares. *Statistical strategies for small sample research*, 1(1):307–341, 1999. 28

A. H. Church and J. Waclawski. *Alternative validation strategies: Developing new and leveraging existing validity evidence*, volume 19. John Wiley & Sons, 2007. 33

G. A. Churchill Jr. A paradigm for developing better measures of marketing constructs. *Journal of marketing research*, 16(1):64–73, 1979. 34

L. J. Cronbach. Coefficient alpha and the internal structure of tests. *psychometrika*, 16(3): 297–334, 1951. 31

E. P. Davila, H. Florez, L. E. Fleming, D. J. Lee, E. Goodman, W. G. LeBlanc, A. J. Caban-Martinez, K. L. Arheart, K. E. McCollister, S. L. Christ, et al. Prevalence of the metabolic syndrome among us workers. *Diabetes care*, 33(11):2390–2395, 2010. 1

J. De Vries, H. J. Michielsen, and G. L. Van Heck. Assessment of fatigue among working people: a comparison of six questionnaires. *Occupational and environmental medicine*, 60 (suppl 1):i10–i15, 2003. 13

J. De Vries, H. Michielsen, G. L. Van Heck, and M. Drent. Measuring fatigue in sarcoidosis: the fatigue assessment scale (fas). *British journal of health psychology*, 9(3):279–291, 2004. 14, 15

R. F. DeVellis. *Scale development: Theory and applications*, volume 26. Sage publications, 2016. 31

A. Dittner and T. Chalder. Measuring symptoms and fatigue severity. 2003. 15

A. J. Dittner, S. C. Wessely, and R. G. Brown. The assessment of fatigue: a practical guide for clinicians and researchers. *Journal of psychosomatic research*, 56(2):157–170, 2004. 1

B. K. Evans and D. G. Fischer. The nature of burnout: A study of the three-factor model of burnout in human service and non-human service samples. *Journal of Occupational and Organizational Psychology*, 66(1):29–38, 1993. 16

F. I. Fawzy, N. Cousins, N. W. Fawzy, M. E. Kemeny, R. Elashoff, and D. Morton. A structured psychiatric intervention for cancer patients: I. changes over time in methods of coping and affective disturbance. *Archives of general Psychiatry*, 47(8):720–725, 1990. 11

L. R. Gay, G. E. Mills, and P. W. Airasian. Educational research: Competencies for analysis and application. 1992. 42

D. Geroge and P. Mallery. Spss for windows step by step: A simple guide and reference, 2003. 39

V. González-Romá, W. B. Schaufeli, A. B. Bakker, and S. Lloret. Burnout and work engagement: Independent factors or opposite poles? *Journal of vocational behavior*, 68 (1):165–174, 2006. 5

E. Grandjean. Fatigue in industry. *Occupational and Environmental Medicine*, 36(3):175–186, 1979. 9

R. M. Guion. Content validity—the source of my discontent. *Applied Psychological Measurement*, 1(1):1–10, 1977. 33

P. A. Hancock and P. A. Desmond. *Stress, workload, and fatigue*. CRC Press, 2000. 3, 11

P. A. Hancock and W. B. Verwey. Fatigue, workload and adaptive driver systems. *Accident analysis & prevention*, 29(4):495–506, 1997. 11

J. K. Harter, F. L. Schmidt, and T. L. Hayes. Business-unit-level relationship between employee satisfaction, employee engagement, and business outcomes: a meta-analysis. *Journal of applied psychology*, 87(2):268, 2002. 18

S. N. Haynes, D. Richard, and E. S. Kubany. Content validity in psychological assessment: A functional approach to concepts and methods. *Psychological assessment*, 7(3):238, 1995. 33

T. R. Hinkin. A review of scale development practices in the study of organizations. *Journal of management*, 21(5):967–988, 1995. 33

C. Jackson. The chalder fatigue scale (cfq 11). *Occupational Medicine*, 65(1):86–86, 2015. 16

S. S. Kahai and R. B. Cooper. Exploring the core concepts of media richness theory: The impact of cue multiplicity and feedback immediacy on decision quality. *Journal of management information systems*, 20(1):263–299, 2003. 28

W. A. Kahn. Psychological conditions of personal engagement and disengagement at work. *Academy of management journal*, 33(4):692–724, 1990. 4, 17

H. F. Kaiser. The application of electronic computers to factor analysis. *Educational and psychological measurement*, 20(1):141–151, 1960. 13

P. Khaengkhun, P. Bhuanantanondh, K. Mekhora, and C. Jalayondeja. D8-2 association between subjective and objective assessment of fatigue. *The Japanese Journal of Ergonomics*, 53(Supplement2):S652–S655, 2017. 14

H. J. Kim, K. H. Shin, and N. Swanger. Burnout and engagement: A comparative analysis using the big five personality dimensions. *International Journal of Hospitality Management*, 28(1):96–104, 2009. 16

B. Kitchenham and S. L. Pfleeger. Principles of survey research: part 5: populations and samples. *ACM SIGSOFT Software Engineering Notes*, 27(5):17–20, 2002. 26

L. B. Krupp, L. A. Alvarez, N. G. LaRocca, and L. C. Scheinberg. Fatigue in multiple sclerosis. *Archives of neurology*, 45(4):435–437, 1988. 11

L. B. Krupp, N. G. LaRocca, J. Muir-Nash, and A. D. Steinberg. The fatigue severity scale: application to patients with multiple sclerosis and systemic lupus erythematosus. *Archives of neurology*, 46(10):1121–1123, 1989. 11

J. M. Lattin, J. D. Carroll, and P. E. Green. *Analyzing multivariate data*. Thomson Brooks/Cole Pacific Grove, CA, 2003. 31

K. A. Lee, G. Hicks, and G. Nino-Murcia. Validity and reliability of a scale to assess fatigue. *Psychiatry research*, 36(3):291–298, 1991. 3, 11

S. S. Leone, M. Huibers, J. A. Knottnerus, and I. Kant. Similarities, overlap and differences between burnout and prolonged fatigue in the working population. *QJM: An international journal of medicine*, 100(10):617–627, 2007. 5, 19

G. Lewis and S. Wessely. The epidemiology of fatigue: more questions than answers. *Journal of epidemiology and community health*, 46(2):92, 1992. 11

L. Lu, F. M. Megahed, R. F. Sesek, and L. A. Cavuoto. A survey of the prevalence of fatigue, its precursors and individual coping mechanisms among us manufacturing workers. *Applied ergonomics*, 65:139–151, 2017. 2

P. Manu, T. J. Lane, and D. A. Matthews. Chronic fatigue syndromes in clinical practice. *Psychotherapy and psychosomatics*, 58(2):60–68, 1992. 2

C. Maslach. leiter, mp the truth about burnout. *San Francisco, CA: Jossey—Bas Publishers*, 1997. 4

C. Maslach. A multidimensional theory of burnout. *Theories of organizational stress*, 68:85, 1998. 16

C. Maslach and M. Leiter. The thruth about burnout, 1997. 16

C. Maslach, S. E. Jackson, M. P. Leiter, W. B. Schaufeli, and R. L. Schwab. *Maslach burnout inventory*, volume 21. Consulting psychologists press Palo Alto, CA, 1986. 5, 16

C. Maslach, W. B. Schaufeli, and M. P. Leiter. Job burnout. *Annual review of psychology*, 52(1):397–422, 2001. 19

D. R. May, R. L. Gilson, and L. M. Harter. The psychological conditions of meaningfulness, safety and availability and the engagement of the human spirit at work. *Journal of occupational and organizational psychology*, 77(1):11–37, 2004. 17

R. P. McDonald. *Test theory: A unified treatment*. psychology press, 2013. 31

H. J. Michielsen, J. De Vries, G. L. Van Heck, F. J. Van de Vijver, and K. Sijtsma. Examination of the dimensionality of fatigue. *European Journal of Psychological Assessment*, 20(1):39–48, 2004. 11

B. Muscio. Is a fatigue test possible? *British Journal of Psychology*, 12(1):31, 1921. 11

D. L. Nelson and B. L. Simmons. Health psychology and work stress: A more positive approach. 2003. 17

Y. I. Noy, W. J. Horrey, S. M. Popkin, S. Folkard, H. D. Howarth, and T. K. Courtney. Future directions in fatigue and safety research. *Accident Analysis & Prevention*, 43(2): 495–497, 2011. 9

NSC. *Fatigue in the Workplace: Causes Consequences of Employee Fatigue*, 2017. 1, 2

J. C. Nunnally. *Psychometric theory 3E*. Tata McGraw-hill education, 1994. 31

OSHA. *Long Work Hours, Extended or Irregular Shifts, and Worker Fatigue*, 2009. URL https://www.osha.gov/SLTC/workerfatigue/hazards.html. 2

P. Pearson and G. Byars. The development and validation of a checklist measuring subjective fatigue (report no. 56–115). *San Antonio, TX: Brooks Air Force Base, School of Aerospace Medicine*, 1956. 11

R. O. Phillips. A review of definitions of fatigue–and a step towards a whole definition. *Transportation research part F: traffic psychology and behaviour*, 29:48–56, 2015. 14

B. Piper, A. Lindsey, and M. Dodd. Fatigue mechanisms in cancer patients: developing nursing theory. In *Oncology nursing forum*, volume 14, page 17, 1987. 14

D. F. Polit and C. T. Beck. *Nursing research: Principles and methods*. Lippincott Williams & Wilkins, 2004. 11

A. Rabinbach. *The human motor: Energy, fatigue, and the origins of modernity*. Univ of California Press, 1992. 9

T. Raykov and G. A. Marcoulides. *Introduction to psychometric theory*. Routledge, 2011. 31, 33, 34

E. Ream and A. Richardson. Fatigue: a concept analysis. *International journal of nursing studies*, 33(5):519–529, 1996. 1

J. A. Ricci, E. Chee, A. L. Lorandeau, and J. Berger. Fatigue in the us workforce: prevalence and implications for lost productive work time. *Journal of occupational and environmental medicine*, 49(1):1–10, 2007. 2

N. P. Rothbard. Enriching or depleting? the dynamics of engagement in work and family roles. *Administrative science quarterly*, 46(4):655–684, 2001. 18

A. M. Saks. Antecedents and consequences of employee engagement. *Journal of managerial psychology*, 2006. 5

W. Schaufeli and D. Enzmann. *The burnout companion to study and practice: A critical analysis*. CRC press, 1998. 19

W. B. Schaufeli. Maslach burnout inventory-general survey (mbigs). *Maslach burnout inventory manual*, 1996. 16

W. B. Schaufeli and A. B. Bakker. Utrecht work engagement scale. *Occupational Health Psychology Unit Utrecht University*, 1, 2003. 19

W. B. Schaufeli and A. B. Bakker. Job demands, job resources, and their relationship with burnout and engagement: A multi-sample study. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, 25(3):293–315, 2004. 18, 24

W. B. Schaufeli and T. W. Taris. The conceptualization and measurement of burnout: Common ground and worlds apart. *Work & Stress*, 19(3):256–262, 2005. 4, 19

W. B. Schaufeli, A. B. Bakker, K. Hoogduin, C. Schaap, and A. Kladler. On the clinical validity of the maslach burnout inventory and the burnout measure. *Psychology & health*, 16(5):565–582, 2001. 17

W. B. Schaufeli, M. Salanova, V. González-Romá, and A. B. Bakker. The measurement of engagement and burnout: A two sample confirmatory factor analytic approach. *Journal of Happiness studies*, 3(1):71–92, 2002. 4, 18, 19

W. B. Schaufeli, A. B. Bakker, and M. Salanova. The measurement of work engagement with a short questionnaire: A cross-national study. *Educational and psychological measurement*, 66(4):701–716, 2006. 18, 39, 54

J. E. Schwartz, L. Jandorf, and L. B. Krupp. The measurement of fatigue: a new instrument. *Journal of psychosomatic research*, 37(7):753–762, 1993. 13

P. Seppälä, S. Mauno, T. Feldt, J. Hakanen, U. Kinnunen, A. Tolvanen, and W. Schaufeli. The construct validity of the utrecht work engagement scale: Multisample and longitudinal evidence. *Journal of Happiness studies*, 10(4):459, 2009. 18

A. Shahid, J. Shen, and C. M. Shapiro. Measurements of sleepiness and fatigue. *Journal of psychosomatic research*, 69(1):81–89, 2010. 3

J. Shen, J. Barbera, and C. M. Shapiro. Distinguishing sleepiness and fatigue: focus on definition and measurement. *Sleep medicine reviews*, 10(1):63–76, 2006. 1

E. Smets, B. Garssen, B. d. Bonke, and J. De Haes. The multidimensional fatigue inventory (mfi) psychometric qualities of an instrument to assess fatigue. *Journal of psychosomatic research*, 39(3):315–325, 1995. 3, 11, 13

M. J. Stokes, R. G. Cooper, and R. H. Edwards. Normal muscle strength and fatigability in patients with effort syndromes. *British Medical Journal*, 297(6655):1014–1017, 1988. 13

J. Studts. Symptom structure of fatigue: a multi-dimensional or uni-dimensional construct for behavioral medicine? *Psychosom Med*, 63:130, 2001. 13

D. Van der Linden, M. Frese, and T. F. Meijman. Mental fatigue and the control of cognitive processes: effects on perseveration and planning. *Acta psychologica*, 113(1):45–65, 2003. 1

J. Vercoulen. The checklist individual strength. *Gedragstherapie*, 32:131–136, 1999. 11

J. C. Wallace. Confirmatory factor analysis of the cognitive failures questionnaire: evidence for dimensionality and construct validity. *Personality and Individual Differences*, 37(2): 307–324, 2004. 15

B. D. Zumbo, A. M. Gadermann, and C. Zeisser. Ordinal versions of coefficients alpha and theta for likert rating scales. *Journal of modern applied statistical methods*, 6(1):4, 2007. 31

Appendix

A IRB Approval Letter

THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

March 02, 2020

Rupy Sawhney
UTK - College of Engineering - Administration - Engineering

Re: UTK IRB-19-05340-XM
Study Title: Determining the effect of fatigue and its impact on engagement levels of employees in an uncontrolled environment

Dear Rupy Sawhney:

The Human Research Protections Program (HRPP) reviewed your application for the above referenced project and determined that your application is eligible for **exempt** review under 45 CFR 46.101. Category 2: Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: i. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; ii. Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or iii. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by .111(a)(7).

Your application has been determined to comply with proper consideration for the rights and welfare of human subjects and the regulatory requirements for the protection of human subjects. This letter constitutes full approval of your application (Version 1.2).

Approval Information:
Exempt cat 2; Ss = 200; consent statement

Approved Study Materials
IRB Application v1.2
Consent Form - Prashanth v1.1
Employee Fatigue Assessment Scale v1.1

In the event that volunteers are to be recruited using solicitation materials, such as brochures, posters, web-based advertisements, etc., these materials must receive prior approval of the IRB.

Any alterations (revisions) in the protocol must be promptly submitted to and approved by the UTK Institutional Review Board prior to implementation of these revisions. You have individual responsibility for reporting to the Board in the event of unanticipated or serious adverse events and subject deaths.

Sincerely,

Colleen P. Gilrane

Colleen P. Gilrane, Ph.D.
Chair

B Fatigue Assessment Scale

Employee Fatigue Assessment Scale – Clayton Homes

Age:

Greetings everyone! The focus of this survey is to improve the quality of life of all employees in the organization. The survey requires you to mention your age for demographic purposes only. Your responses will always be maintained anonymous. The answers that you provide to the survey are valuable in increasing the overall quality of life of all employees and may not be directly beneficial to you. Please respond to the best of your knowledge and memory. Thank you!

Instructions:

- All survey questions use the following response scale:
  1. Never 2.Rarely 3.Occasionally 4. Sometimes 5. Frequently 6. Usually 7. Always
- Please answer by circling one response.
- Choose one number per question.

	Never	Rarely	Occasionally	Sometimes	Frequently	Usually	Always
1. After finishing the day's work, you step out to head home, do you feel physically exhausted to drive?	1	2	3	4	5	6	7
2. Apart from the normal breaks, do you feel the need to take rest at frequent intervals while working?	1	2	3	4	5	6	7
3. At the end of the day do you perform tasks at a much slower pace compared to the mornings?	1	2	3	4	5	6	7
4. As the day progresses, do you see youself yawning ?	1	2	3	4	5	6	7
5. After permorming most of your tasks in one floor, do you get tired very	1	2	3	4	5	6	7

	quickly or catch your breath?							
6.	While performing labour intensive tasks, do you feel fed up doing it?	1	2	3	4	5	6	7
7.	By performing the same job over and over again, does it give the feel of being monotonous?	1	2	3	4	5	6	7
8.	While performing a task, how often do you have a lapse in concentration?	1	2	3	4	5	6	7
9.	Do you physically feel that you are in a bad condition while performing intense tasks like lifting plywood sheets or any heavy item?	1	2	3	4	5	6	7
10.	How often does your thoughts wander while performing a task?	1	2	3	4	5	6	7
11.	Thinking about the intensive tasks that you have to perform at work, how often do you not feel motivated to turn up for work?	1	2	3	4	5	6	7
12.	While performing intense tasks, do you feel less strength in your muscles?	1	2	3	4	5	6	7
13.	Does bending, walking with loads, naling, climbing stairs cause stiffness in your arms and legs?	1	2	3	4	5	6	7
14.	While lifting heavy objects, do you feel pressure and stiffness in your shoulder?	1	2	4	4	5	6	7
15.	During the course of your daily routine, do your eyes feel strained?	2	3	3	5	6	7	7
16.	Does the lack of temperature regulator inside the plant makes you feel uncomfortable?	1	2	3	4	5	6	7

Vita

Prashanth Ganapathiagraharam Balasubramanian was born in Chennai, Tamilnadu India. He graduated with a Bachelor's degree in Mechanical Engineering from Anna University, Chennai. He worked for two and a half years with PTC inc. India Ltd as an Application Engineer/Team Lead. He further pursued his Master's degree in the field of Industrial and Systems Engineering at the University of Tennessee, Knoxville. During that time, he worked under the guidance of Dr. Rupy Sawhney as a graduate research assistant and a graduate teaching assistant.