EVIDENCE-BASED EVALUATION OF PSYCHOSOCIAL RISK FACTORS AND THE INTERACTION OF THEIR STRESSORS USING SYSTEM DYNAMICS

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ABSTRACT

The experience of work-related stress caused by exposure to psychosocial risks can lead to poor physical and mental health, loss of productivity and ultimately results in worker injury. Considering that the impact of psychosocial risks may vary on an individual basis and the nature of the associated stressors varies widely among workplaces, this paper examines the latest research trend in this discipline by analyzing published psychosocial research in several journals in terms of contributions of institutions, adopted data collection and processing methods, and research interest. In addition, a database resulting from an evidence-based assessment of key psychosocial risk factors is provided and a conceptual System Dynamics (SD) model is created accordingly to illustrate the interaction between identified variables. The developed causal loop diagrams can better delineate the mechanism underlying the causal relationship between a given psychosocial factor and its adverse effects. The outputs are expected to assist project managers in gaining an in-depth understanding of the complexity and interaction of psychosocial factors and their outcomes.

Keywords: work-related musculoskeletal disorders, psychosocial risk factors, ergonomics, system dynamics.

1. INTRODUCTION

Workplace psychosocial factors are non-physical aspects of a workplace developed by the policies, culture, expectations, and social attitudes of the organization (CCOHS, 2012). Workers' behaviors are not random and occur due to external factors. In fact, psychosocial factors can be defined as factors associated with the way individuals react to the work environment and their job demands (Visagie, Swanepoel, and Ukpere, 2014). To implement effective, efficient and sustainable ergonomic interventions, it is important to understand how the way in which work is organized influences workers' biomechanical exposures, psychosocial stresses, and the relationships between these factors (Bao et al., 2015).

Previous studies identify a significant association between psychosocial work stressors and workers' work-related musculoskeletal disorder (WRMSD) symptoms (Eatough, Way and Chang 2012; Visagie, Swanepoel and Ukpere 2014; Thiese, et al. 2015; Bao, et al., 2015). For instance, factors such as job roles and responsibilities, control over work, and safety climate at work are shown to be related to increased risk of WRMSDs (Eatough, Way, and Chang, 2012). Similarly, factors such as job satisfaction, co-workers' support, physical and mental exhaustion, general health, and anxiety are shown to have a significant impact on the risk for the development of WRMSDs (Thiese et al., 2015; Widanarko et al., 2015). Other factors, including job insecurity and long and irregular working hours, may increase stress and consequently increase psychosocial risk.

Although occupational health and safety management systems address both health and safety in the workplace, several researchers argue that they focus mostly on safety rather than on workers' health. Also, there is a lack of understanding regarding the process mechanisms, such as how psychological stressors interact with one another, leading to adverse effects on employees' health. Therefore, this paper presents a complete integrated assessment for various working conditions from the perspective of reducing the risk of psychosocial factors and provides a list of psychosocial risk factors. First, a systematic literature review is conducted to ensure a comprehensive search of various databases to build an evidence-based assessment in the area of psychosocial risk factors. Then, a conceptual causal loop diagram is created to illustrate the interaction between psychosocial stressors based on research of modeling stresses and the review of various meta-models for stress.

System thinking, which is a compelling solution for many real-world problems, refers to the paradigm in which the world is seen as a complex system, in which everything is connected to everything else (Sterman, 2001). The deployment of system dynamics in this study allows for recognizing the problem of psychosocial risks in the workplace and describing its underlying mechanism through causal loop diagrams also known as the influence diagrams. The present study aims to advance the knowledge of the mechanisms through which job stressors influence safety outcomes, which can ultimately enhance the development of stress management and safety-related interventions. The findings are expected to assist project managers and job designers in the following ways: (i) estimate the impact of mental disorders on employees' health in order to set priorities and plan appropriate interventions in the workplace; (ii) explore the mindset which could trigger unwanted behavior within a psychosocial work

environment; and (iii) investigate the mechanisms underlying the associations between psychological risk factors and their adverse outcomes through the developed causal links.

2. A REVIEW OF THE RESEARCH ON PSYCHOSOCIAL RISKS

In the interest of addressing psychosocial risks in the workplace, an impressive number of studies have been published by internationally renowned journals related to health and safety management in the construction industry. However, the absence of a holistic summary of the research developments in the discipline of psychosocial risk management is apparent. Therefore, a literature review is presented based on searches using electronic search engines and different online databases (e.g., Google Scholar, Science Direct, Web of Knowledge/Science, Concordia University's library catalogue) for relevant published articles that include the following key words: work-related stress, psychosocial risks, psychosocial risks assessment/management, musculoskeletal disorders, work stress/organization, and psychosocial risk mitigation/interventions. The articles from the search results are scanned to filter and retrieve related papers.

Accordingly, psychosocial-related literature can be categorized into the following areas: guidelines and standards, risk auditing approaches, single item-based studies, and meta-stress analysis researches. In the following paragraphs, different research traditions and study areas of psychosocial factors are reviewed. Figure 1 presents the academic journals through which the reviewed articles were published.

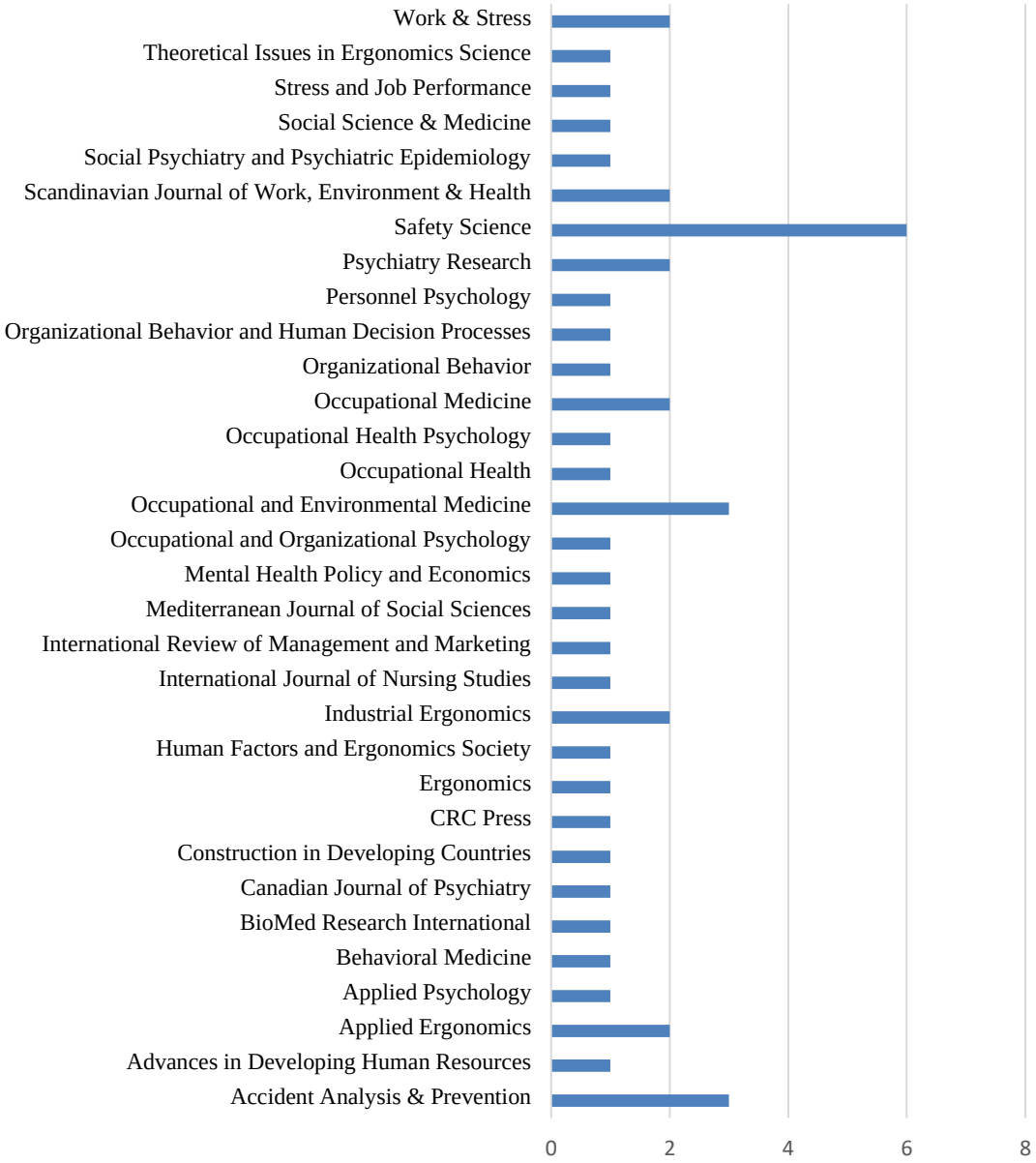

Figure 1. Psychosocial related articles reviewed in this study and their associated journals

To gain insight on the primary research stream in this domain through the reviewed articles, the contribution of each institution is quantitatively assessed using the score developed by (Howard, Cole, and Maxwell, 1987) by means of the following formula:

$$Score = \frac{1.5^{n-i}}{\sum 1.5^{n-i}} \quad (1)$$

where each paper is assumed to have a score of one point, n is the total number of authors of the article and i is the ordinal position of the author of the article. For example, in a paper with two authors, the institution associated with the first author is given a score of 0.60 and the second author's institution is given 0.40. Table 1 presents the contribution score of each institution based on the reviewed articles.

In addition to the reviewed research on psychosocial risks, a number of guidelines and initiatives have been developed focusing on the management of the psychosocial work environment, including: the Canadian Standard for Psychological Health and Safety in the Workplace (National Standard of Canada, 2013), which is a suitable standard and provides guidelines to prevent psychological harm of workers across all sectors; World Health Organization (WHO, 2010), a global framework that combines evidence-based approaches and principles of health protection; The European framework for psychosocial risk management (PRIMA-EF) (Leka and Cox, 2008), and PAS1010, the British Standards Institution (BSI) guidelines that establishes the benchmark for the evaluation of psychosocial risks (BSI, 2011). Despite several occupational health and safety management systems, it can be argued that their primary focus is on workers' safety rather than workers' health (Bergh et al. 2016; Hasle, 2011).

Psychosocial risk auditing approaches (Bergh, Hinna, Leka, and Zwetsloot, 2016), and the establishment of the psychosocial exposure indicator (Bergh et al., 2014) are effective tools to confirm compliance to requirements in the management system and to monitor the status of influential psychosocial risks in the workplace based on

Table 1. Institutions and their contribution scores based on the reviewed articles

Institution	***Score***
Albert Einstein College	0.32
Asian Institute of Technology, Pathumthani	1.00
Babson College	1.00
California Department of Health Services	0.12
Central Michigan University	0.68
Columbia University, USA	0.80
Finnish Institute of Occupational Health	0.40
Global Established Pharma Medical Affairs, Japan	1.00
Hebei Medical University, China	0.40
Hiroshima University	1.00
Indiana University	1.00
Institute of Psychiatry, London	0.40
Jichi Medical School	0.12
Keele University, UK	1.00
Keio University	0.18
Leicester University	0.32
Leiden University Medical Center	0.12
London School of Economics and Political Science	0.60
Louisiana State University	1.00
Massachusetts Institute of Technology	1.00
Massey University, New Zealand	0.47
Michigan State University	0.40
National Institute for Occupational Safety and Health	0.21
National Institute of Industrial Health, Japan	0.60
National Institute of Occupational Safety and Health, Japan	0.42
Netherlands Institute of Mental Health and Addiction	0.28
North-West University, South Africa	0.79
Queensland University of Technology, Australia	0.60
Saint Mary's University, Canada	1.00
Seoul National University	0.60
Shenzhen University	0.40
Statoil ASA, Stavanger, Norway	1.20
Swinburne University of Technology, Australia	0.60
The National Research Centre for the Working Environment, Denmark	1.47
TNO Institute of Preventive Health Care	1.00

Institution	***Score***
University Teknologi Petronas	1.00
University College London	0.21
University of Adelaide	0.28
University of Alberta	0.28
University of California	1.88
University of Cincinnati	1.47
University of Florida	1.40
University of Gävle	0.60
University of Hawaii at Manoa	0.60
University of Illinois at Urbana-Champaign	0.42
University of Indonesia	0.32
University of Johannesburg	0.21
University of Lleida	1.00
University of London	0.21
University of Michigan at Ann Arbor	0.18
University of Milan	0.40
University of New South Wales	0.80
University of North Carolina	1.00
University of Nottingham	0.80
University of Seoul	0.40
University of South Australia	0.60
University of South Florida	0.60
University of the Netherlands Antilles	0.18
University of Tokyo	0.28
University of Umeå	0.40
University of Utah	0.81
University of Wisconsin Oshkosh	0.32
University of Wisconsin-Madison	1.00
University of Wisconsin-Milwaukee	0.60
University of Wuppertal, Germany	0.60
Utrecht University	0.12
Vincent's hospital	0.60
Virginia Commonwealth University	0.32
VU University, Netherland	0.42
Washington State Department of Labor and Industries	0.99

Organizational requirements. However, it can also be argued that they are costly and do not necessarily cover the complexity of the work environment or the interaction between psychosocial factors (Hohnen and Hasle, 2011). Furthermore, their findings cannot be directly adapted to other company settings.

Various cross-sectional studies examine the bivariate relationships between psychosocial work stressors and WRMSDs symptoms (Bongers et al. 1993; Nielsen et al. 2008; Kelloway, Mullen and Francis 2006; Wang et al. 2007; Silverstein et al. 2010), as well as the bivariate relationship between biomechanical exposure and psychosocial outcomes (Thiese, et al., 2015). According to (Thiese et al., 2015), as physical exposure (duration, repetition, and force) increases, psychosocial responses worsen. Also increased repetition found to be associated with depression and forceful exertions are shown to be related to physical exhaustion. Factors such as perception of safety climate, and workers' ability to control the pace of the work are found to be correlated with lost work days due to injury (Abbe et al., 2011). Safety-specific leadership behavior, such as emphasizing the value of safe performance and rewarding safety-related compliance, contributes positively to reduction of occupational injuries (Kelloway, Mullen, and Francis, 2006) and have a relationship with mental exhaustion (Nielsen et al., 2008). Also, high job demands, one's perception of the level of workload (Goldenhar, Williams, and Swanson 2003) and job dissatisfaction are found to be significantly associated with arm/hand and lower back disorders (Silverstein et al. 2010; Widanarko et al. 2015). Goldenhar et al. (2003) identified the following stressors to be directly related to injury: job demands, job control, job certainty, job training, safety climate at work, skill under-utilization, responsibility for the safety of others, exposure hours, and job tenure. Also, according to Bongers et al. (1993), low job control and lack of social support by colleagues are positively associated with musculoskeletal disorders (MSDs). One of the limitations of the bivariate studies in addressing the relationship between psychosocial risks and MSDs is that they often include a small number of stressors, making it a challenge to compare the impact of different stressors on outcomes. Results from a study of a sample of workers exposed to different levels of physical and psychosocial risks (Widanarko et al. 2015) indicate that exposure to high physical/high psychosocial levels has more associations with MSDs and presenteeism, and exposure to low physical / high psychosocial levels are more closely related to lower back symptoms than those in the high physical and low psychosocial group. Despite their valuable findings, these studies are based on limited factors and provide conflicting evidence. Additionally, the studies are unable to evaluate the relative impacts of psychosocial stressors on MSDs as the effects of psychosocial stressors and physical exposure on MSD symptoms are often lumped together (Thiese et al., 2015; Widanarko et al., 2015; Smith et al. 2004) and psychosocial factors are treated as potential confounders without evaluation of their independent influence on MSDs. The interaction of physical and psychosocial factors increases the probability of MSDs greater than the sum of the magnitude of the individual effects (Widanarko et al., 2015). All these make it difficult to understand the mechanisms underlying the associations between the stressors and their adverse outcomes.

Exposure to psychosocial risk factors can also affect worker performance, and, if prolonged, may result in serious health problems (Bergh et al., 2016), which are found to have a significant association with presenteeism (Tsuchiya et al. 2012; Plaisier et al. 2012) rather than absenteeism. Asami et al. (2015) establish a direct relationship between strain symptoms and productivity loss, even among workers with undiagnosed depression, implying that workers suffering from stress may not take days off but remain at work, leading to impaired work performance. In Canada, costs associated with presenteeism are shown to be 2.7 times higher than those associated with absenteeism (Evans-Lacko and Knapp 2016). Loss of productivity caused by mental stress is approximately 2.77 to 4.17 days per month for Western workers (Lim, Sanderson, and Andrew 2000), and 28-30 days per year for Japanese (Tsuchiya et al., 2012). Risk factors such as high physiological demand, low decision latitude and job control, and low social support reportedly reduce activity and result in poor performance (Plaisier et al. 2012; Aasa et al., 2005).

According to the literature review, psychosocial data collection methods usually include electronic questionnaires, face-to-face interviews, and survey techniques, in which questions are designed based on different standard questionnaires such as NIOSH Generic Job Stress Questionnaire (Abbe et al. 2011; Goldenhar et al., 2003;Thiese et al., 2015), Job Content Questionnaire (Widanarko et al. 2015; Thiese et al., 2015; Blanch 2016), ERI Questionnaire (Widanarko et al., 2015), HSE Safety Climate Survey Tool (Visagie et al., 2014), NIOSH Management Commitment to Safety Scale (Abbe et al., 2011; Goldenhar et al., 2003), North-Western National Life Insurance Company Survey (Abbe et al., 2011), and the General Well-Being Questionnaire (GWBQ) (Bergh et al., 2014).

Future research directions can be derived based on what has already been carried out to date and what remains to be carried out in the domain of psychosocial risks management. Based on the reviewed sources, suggestions for future studies include: more longitudinal studies toward the analysis of interaction of physiological and psychological factors, and a definite conclusion regarding causal relationships between stressors, strains, and MSD symptoms; exploration of the impact of psychosocial risks exposure on workers performance; and investigation of factors, other than physical exposure, that influence the psychological state of workers. Also, a continuation of research is expected on the role of psychosocial factors as independent contributors to injuries and MSDs.

3. EVIDENCE-BASED LIST OF PRIMARY PSYCHOSOCIAL RISK FACTORS

As a result of the review of the literature retrieved from academic publications, reports, and standards, a total of 19 factors, reported as influential in the emergence and development of psychosocial risks, are identified and summarized in Figure 2. Psychosocial risks present an ongoing challenge related to occupational safety and health (Bergh et al., 2016). While there are various psychosocial stressors found in the literature, various categories are selected by researchers to classify those stressors for further assessments, such as "demands and control" and "social support" (Bongers et al., 1993), "work role", "job control", and "social characteristics and safety leadership" (Eatough et al., 2012; Rosen et al. 2010), or "job demands", "role and responsibilities", "job control", and "social support" (Bergh et al., 2016). In the present study, categories are selected as they represent relatively stable characteristics in the work environment, and, consequently, workers may have prolonged exposure to these psychosocial work stressors. Thus, the identified factors in Figure 2 are categorized into job control, job demand, social support, safety climate, and individual characteristics.

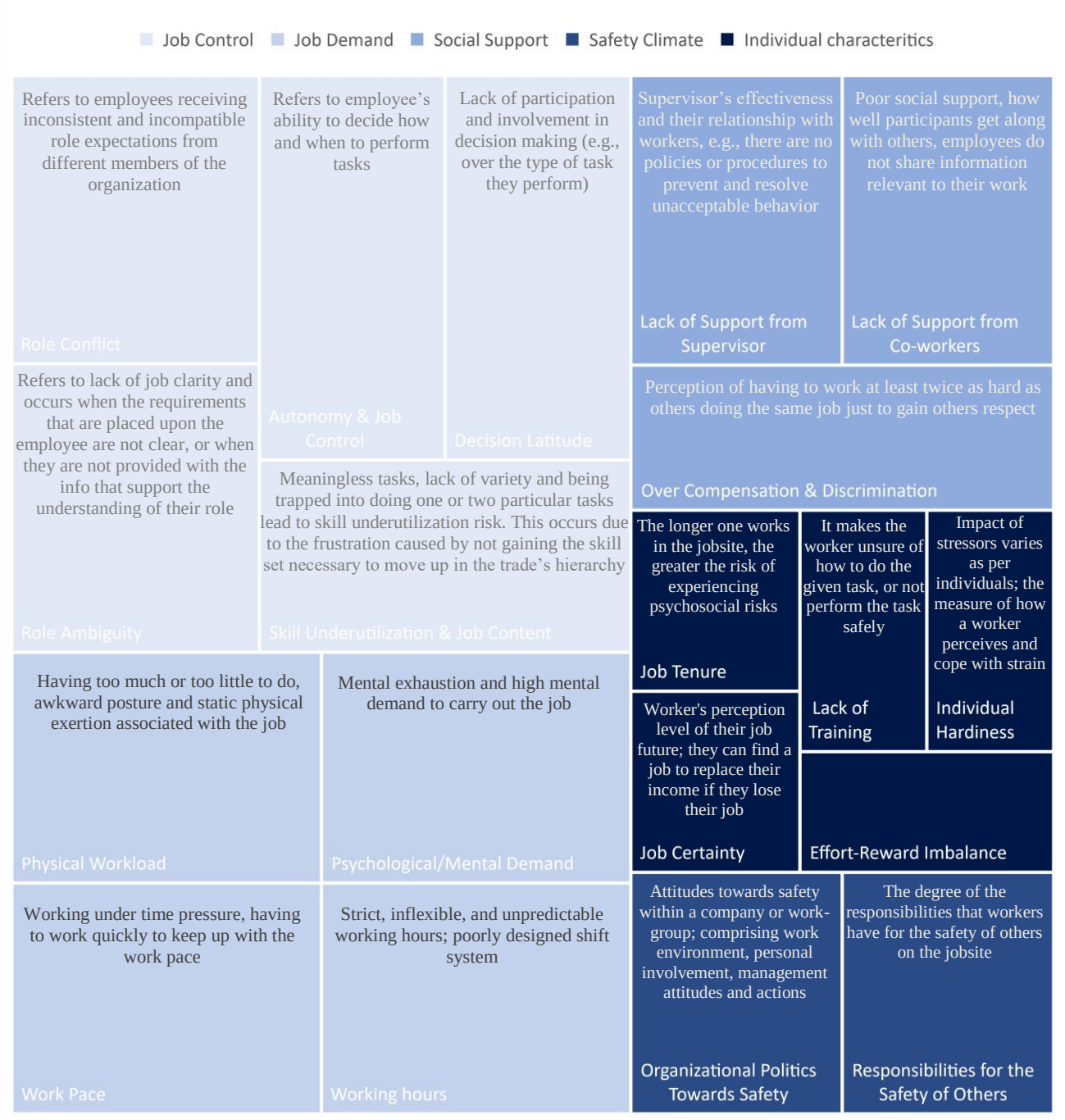

Figure 2.Influential factors in the development of psychosocial strain symptoms, identified in previous literature

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4. SD MODEL DEVELOPMENT

System dynamics is a powerful graphical illustration tool (through its causal mapping), and is effective in representing complex interactions between factors and making the problem more readily understood (Wang, Zou, and Li 2016). It has been utilized for improving construction safety and understanding workers' behavior and safety attitudes and has been proven to provide better and less subjective understanding of the accident and injury mechanism (Wang et al., 2016; Shin et al. 2014; Leveson 2004; Abaeian et al. 2016). Accordingly, introducing the interactions underlying psychosocial risks into a causal feedback model would help to reveal the pathways by which psychosocial risks lead to adverse effects in workers. Thus, this section aims to develop an SD model for better understanding and analyzing the complex feedback mechanism surrounding workers' mental processes due to exposure to psychosocial risks in the workplace.

The deployment of SD allows a four-stage approach: (1) recognizing the problem and breaking it down into smaller systems without violating the holistic concept of SD; (2) describing the system by means of causal loop diagrams also known as influence diagrams; (3) qualitative analysis that involves closely analyzing the causal loops; (4) construction of a simulation model that encompasses the specification of the structure estimation of variables, and behavioral relationships.

4.1 Causal Loop Diagrams

Based on a review of previous research findings and the identified psychosocial factors presented in Figure 2 in addition to in-depth discussion with construction managers and wellness specialists, an SD model is developed using Vensim software, containing the feedback structure of psychosocial risks and their impacts on workers' behavior as well as the pathways by which they lead to MSDs and impaired work performance, as shown in Figure 3.

As represented in Figure. 3a social support is a consistent mediator in the association of job control with job strain and thus is positively related to job control (Goldenhar et al., 2003; Blanch 2016). According to Blanch (2016) 70% of the variance in job strain is due to the mediation effect of job control through social support in addition to the large direct effect of job demand. While the safety climate at work is positively related to a perceived level of social support (Goldenhar et al., 2003), an increased level of social support, and, specifically more effective contact with supervisor and more effective supervision can further result in a better perception of safety climate (Han et al. 2014).

Strain results from a mismatch of psychosocial risks placed upon workers (including job demand, level of control and social support, perception of safety climate and effort-reward imbalance) and their psychological capabilities to cope with them. However, a combination of high demands and a high level of control can lead workers to experience a heightened sense of "personal accomplishment & feeling of competence" (Dollard et al., 2000). The outcome of strain may also interact with the environment and respond by impacting the level of work-related stress, leading to exaggerated perceived symptoms (Goldenhar et al., 2003; Sauter & Swanson, 1996). According to Thiese, et al. (2015) individual factors can affect the psychosocial measures either through the perceived level of strain or capabilities to cope with strain. As it takes some time for workers to recognize the risk and change their subjective risk based on their psychological hardiness, "time perceiving coefficient" is represented in the model to reflect the time it would take for the individual to perceive the risk.

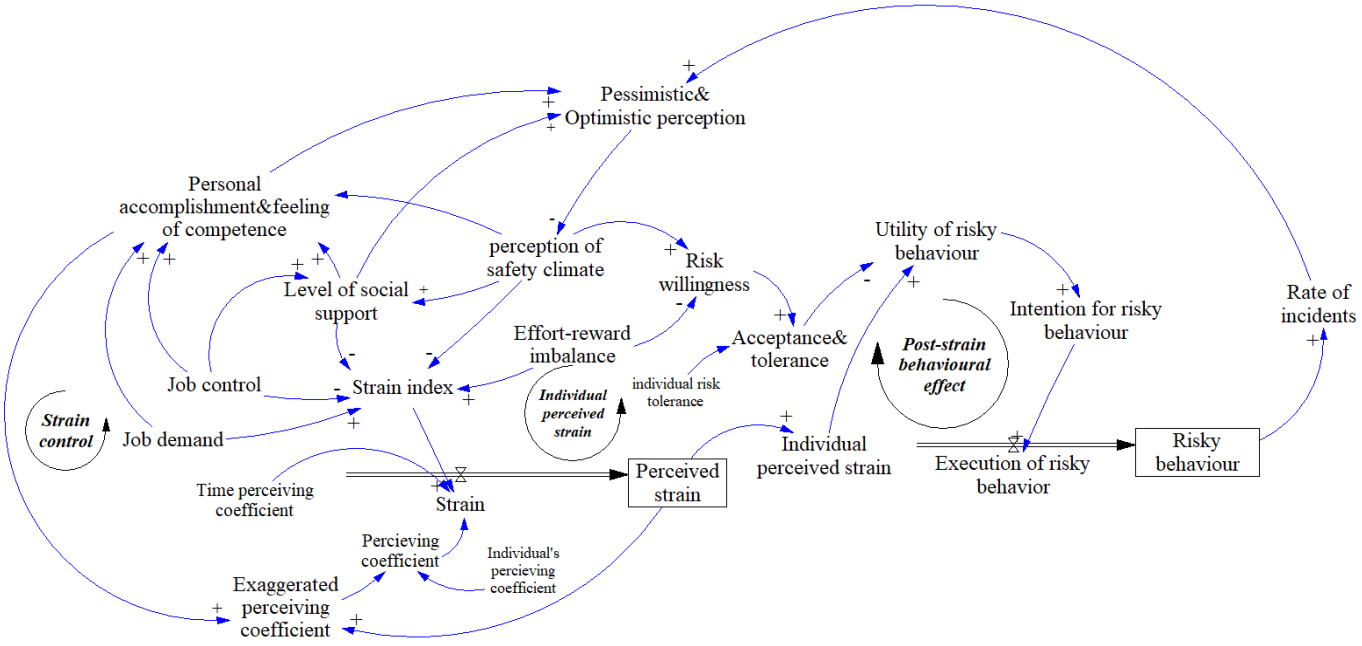

Figure 3a. SD model development

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This indicates that the better the individual hardiness, the longer it would take for the individual to perceive the strain. Also, previous studies suggest the exploration of how psychological dimensions of hardiness and conscientiousness, may moderate the relationship between psychosocial work -stressors and strain. Thus, "individual's perceiving coefficient" variable is represented in the model to explore this mediation and evaluate various perceived strains among different individuals based on workers' psychological capacity by buffering their stressful experiences. This implies that the better an individual's psychosocial hardiness, the lower their perceiving coefficient would be. Individual risk tolerance plays a key role during objective risk assessment and thus is represented in the model as a function of individual tolerance and risk willingness (whether the worker wants to take the risk). In addition, proactive effort-reward measures and better perception of safety climate can affect the risk willingness. Strain plays a mediating role in linking job stressors and unsafe behaviors, including execution of risky behavior which includes any activity or behavior that deviates from normal accepted safety procedure. Execution of risky behavior increases the likelihood of accidents, leading to lower perception of safety climate in the workplace. This is represented in the model, through "pessimistic & optimistic variable". When workers engage in risky behavior due to prolonged exposure to poor working conditions, the workers may establish a new habit and act less safely in performing the task, as modeled in Figure 3b.

The signs and symptoms of strain tend to progress through different phases. Fig 3b illustrates further stages in which bio-physiological reactions begin to develop, leading to an increase in the likelihood of fatigue and compounded level of job demand that workers are under when performing the task. Fatigue itself can lead to worker deterioration of cumulative experience on a site (Love and Edwards 2004) and can increase the progression of warning signs, leading to a greater chance of fatigue and MSDs.

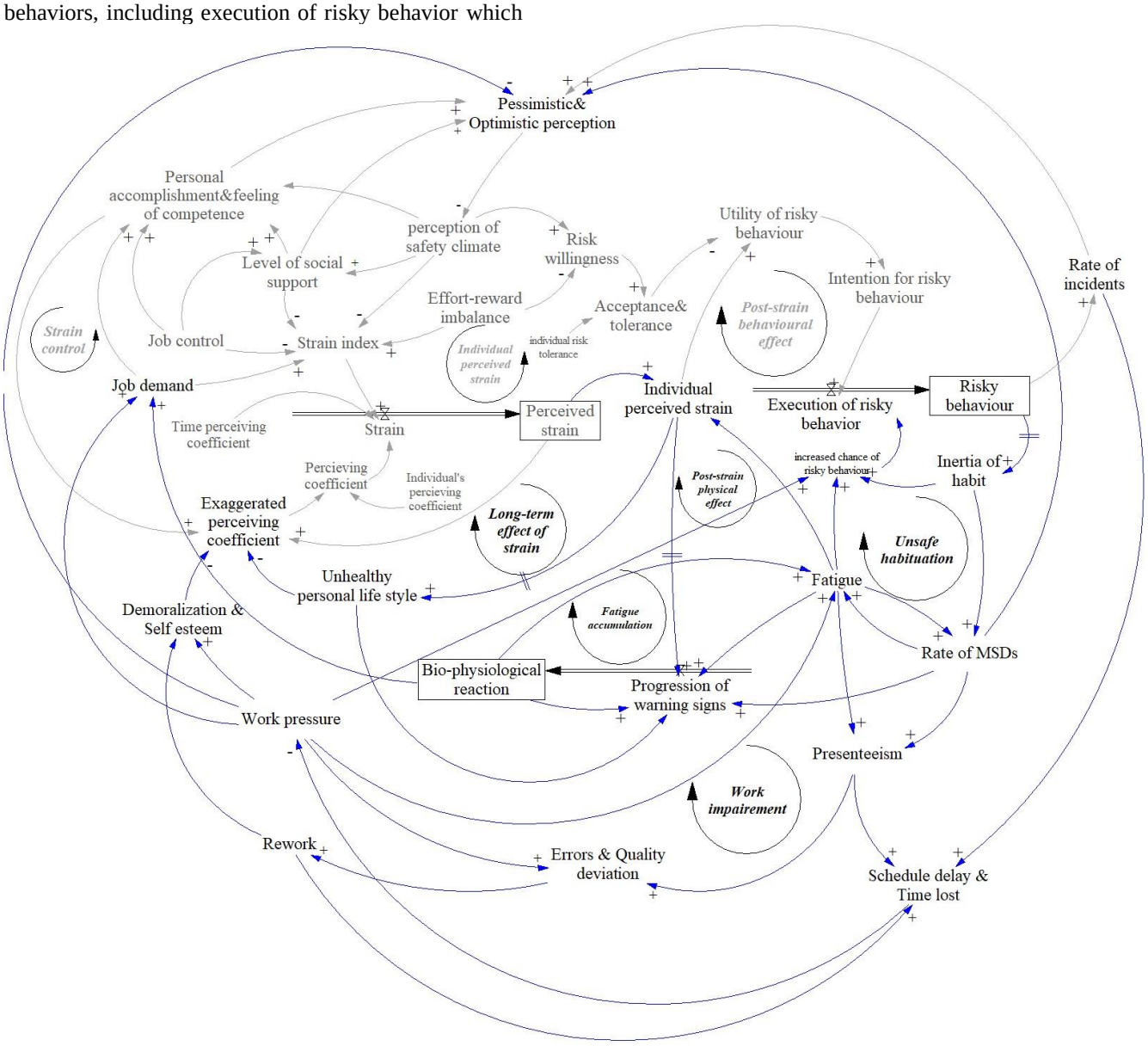

Figure 3b. SD model development

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Psychosocial risk factors and their strain outcomes are shown to be more largely associated with presenteeism than absenteeism (Tsuchiya et al., 2012; Asami et al., 2015), thus the developed model focuses on the impaired work performance due to exposure to psychosocial risks in the workplace. According to CCOHS (2012), when presenteeism occurs, workers come to work, but are not fully functioning or mentally present due to stress or sickness, which in turn results in a greater chance of making errors, leading to rework and schedule delays, and consequently work pressure. Perceiving production pressure implies excessive workload, and higher levels of job demand, and also influences workers' perception of safety at work.

Eventually, if the early behavioral warning signs and physiological symptoms are ignored, workers' psychological well-being and their personal life style could be affected (change in sleeping routine, smoking habits, loss of sex drive, and alcohol abuse).

5. DISCCUSION & CONCLUSION

Psychosocial work stressors may have complex effects on strain and workers' health beyond simple bivariate relationships (Eatough et al., 2012; Bao et al., 2015). To gain an in-depth understanding of the research on psychosocial risk management, this study presents a systematic review of related articles and provides a list of psychosocial risk factors. Also, based on the reviewed articles, journal publications and the contributions of institutions on psychosocial research are analyzed using different methods of data collection, and the research trend as well as different categories for the discipline of psychosocial research are reviewed.

The literature review indicates that despite different stress process-based models, specific conclusions cannot be drawn in relation to the complexity of interaction and the mechanisms underlying the relationships between key psychosocial variables. Thus, an SD model is developed to illustrate the interaction between identified stressors and their adverse effects. The proposed SD model provides a useful tool for hypothesizing the structure that underpins the mechanism of psychosocial risk. This allows decision makers to evaluate the complex feedback process due to exposure to psychosocial risk factors. According to Coyle (1999), qualitative SD describes a system and the description "is in itself a useful thing to do which might lead to better understanding of the problem in question". As an initial effort to evaluate the impacts of psychosocial risks as well as their underlying interactions from a holistic view, this study pursues behavior prediction rather than point prediction. Future research will involve actual data collection to quantitatively assess the workers' mental processes due to exposure to psychosocial risks.

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