THE TRANSFORMATION MECHANISM OF WORK-RELATED STRESS INTO UNSAFE BEHAVIOUR IN CONSTRUCTION INDUSTRY: BASED ON DEA METHOD

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During the last decade, increasing attention has been paid to the problem of work-related stress and mental health in the construction industry. Numbers of correlative studies have shown that work-related stress will directly or indirectly affect the performance of individuals and organizations, even may present itself in the form of unsafe behaviour. As one of the most significant causes of safety accident, the unsafe behaviour will bring immeasurable harm and loss to individuals and organizations. However, there is a relative lack of studies that provide clarity on underlying causes and the transformation principle of work-related stress into unsafe behaviour. In order to further study the relationship between work-related stress and unsafe behaviour, this paper carries out two-step research. Firstly, based on Robbins' stress theory model and unique the construction industry's unique working pressure incentives, this paper finds out that there are certain differences in the work-related stress sources of construction industry managers and constructors and collates the mechanism model 'work pressure source-work pressure experience-unsafe behaviour' from the manager's point specific to the construction industry. Secondly, considering the difficulties to quantify the relationship formula between the work-related stress and the unsafe behaviour, Data envelopment analysis (DEA), a multi-index analysis method that does not need to determine the weight and function relationship, is selected. Through interviews and investigations with 15 on-site construction projects' safety managers, this paper quantifies the situation of pressure sources and the frequency of unsafe behaviour in 15 projects and substitutes into the DEA model to verify the current correlation between the indicators and the work-related stress transformation effectiveness of each project. The sensitive of the work-related stress sources is determined by comparing the differences between the effective units and the invalid units, so as to propose the opinions on controlling the sources of work-related stress. The final analysis shows that a lack of social support, short job tenure and conflict demand are the three main stressors that need further attention in the construction of the factory.

Keywords: data envelopment analysis, Robbins' stress model, work-related stress

INTRODUCTION

With the accelerating pace of contemporary social life, workers from all industries began to feel a certain degree of work-related stress. In the construction industry, work-related stress has become an inherent feature of the workplace environment and

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can negatively transcend into family and personal lifestyles if not appropriately managed (CIOB, 2006). Loosemore and Waters (2004) pointed out that the increasing level of stress may present itself in the form of unsafe working practices, lower morale, higher turnover and poorer performance. The construction industry is one of the most risky industry (Li *et al*., 2015; Wang *et al*., 2016). In 2017, the Ministry of Housing and Urban-Rural Development of China announced a total of 692 safety accidents and 807 deaths in public housing projects. Construction workers' unsafe behaviour is one of the main causes of safety accidents and still needs continuous attention and research. It has been widely reported that there is a close connection between work-related stress and unsafe work behaviour, though very limited studies about the transformation mechanism between them have been undertaken (Dong-Chul Seo 2005; Choudhry 2008; Fogarty 2010). Currently, studies on workers' unsafe behaviour always mention the negative impact of work-related stress on them (Brande *et al*., 2016, Dan Wang *et al*., 2018). However, the causes of work stress and the key role it played are often overlooked. Golparvar (2011) proposed a "pressure-imbalance-compensation model" through empirical research. The study pointed out that when employees feel work stress, their psychological perception and safety behaviour will appear unbalanced, and employees will do abnormal actions to seek inner balance. Dan Wang (2018) examined the predictive powers of safety-related stress and psychological capital (PsyCap) on safety behaviour, and the moderating role of PsyCap on the safety-related stress-behaviour relationship. Psychology believes that human behaviour will first be driven by psychological activity, and later external behaviour can predict the law of mental activity. Therefore, the inference of unsafe behaviour of employees to prevent the occurrence of safety accidents cannot be judged simply by analysing factors such as the safety atmosphere, the professional skills of workers, and the mastery of safety knowledge. More intuitive consideration, such as the abnormal actions caused by psychological factors, should also be considered as the reason of unsafe behaviour.

Research on work-related stress and unsafe behaviours is still a hot topic. This paper based on the understanding of the theory that work stress will present itself as unsafe behaviours and the work stress, as a subjective psychological factor, is difficult to quantify it and find specific function relationship. In addition, the simple correlation analysis cannot provide more guidance for actual work pressure control. Thus, this paper decided to select DEA method for in-depth study of the model for two reasons: 1) DEA method was used to analysis the relationship between abstract multiple indicators and does not need to determine the characteristics of index weights and function relationships. 2) DEA method was used to analyse the connection about safety atmosphere and employee safety behaviours in construction industry. After the two-step research, this paper can provide a basic work-related stress transformation model framework in construction industry and some advice for actual work-related stress transformation control.

LITERATURE REVIEW

Work-Related Stress

Since the 20th century, scholars have conducted more in-depth research on work-related stress. However, there is no general explanation for the definition of it. In the United Kingdom, for example, in the official documents published by the Health and Safety Executive organization (2004) stated stress is the adverse reaction a person has to excessive pressure or other types of demand placed upon them. In the United

States, the National Institute for Occupational Health and Safety (1999) defined work-related stress as "the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker. Job stress can lead to poor health and even injury." In China, scholars also have relevant definitions of work-related stress. For example, Xu *et al*., (2004) believe that work-related stress is a series of reaction processes formed by individuals under the continuous action of stressors.

Although, when compared to other industries, the construction sector has relatively low levels of reported work-related stress, it is still a topic of concern for the industry (HSE, 2007). Different scholars have put forward different views on the study of the causes of work-related stress in construction field. A study of 36 construction site managers in the UK identified ten key stressors for construction managers using a stress audit in one company (Sutherland and Davidson, 1993). Gunning and Cooke (1996) in their Northern Ireland questionnaire study, also identified some specific stressors for two groups of construction professional such as working to impossible deadlines, client demands, hiring/firing staff, working on multiple projects and conflict within the firm. According to the document "An analysis of the prevalence and distribution of the stress in construction industry" (2007) published by the British official HSE organization, workers cannot change the process according to their own wishes and do not receive adequate support and assistance are the two main aspects where workers in construction industry feel more pressure than other industries. In addition, Madine (2000) and other scholars found that construction workers stress mainly come from the following stressors: Shorter deadlines, longer working hours, signing of short-term contracts, increased competition, fines and the industry constantly raise productivity.

Based on telephone interview study of 408 construction labourers, Goldenhar, Williams and Swanson (2003) also identified a number of possible stressors and how they link to negative safety outcomes such as injuries and near-misses. What's more, the main stressors related to injuries and near-misses were: Job demands, Job control, Job certainty, Safety climate and so on. The most significant stressors identified by construction managers have been work overload, role ambiguity and conflict, unpaid overtime restrictive career progression, the diverse range of personalities encountered in their work environment, commuting, changing technology, redundancy, client demands, limited resources, financial pressures, and budget constraints (CIOB, 2006). Paul Bowen and other scholars (2014) build a work-related stress structural equation model and find that age, gender, level of job control, and organizational climate are significant predictors of stress discrimination.

So far, there are three main research theories about the concept of work-related stress: Stimulus theory, reaction theory, and stimulus-response theory. Weiss (1983) is the representative scholar of stimulus theory, he believes that work-related stress is a psychological reaction that a person presents when receiving external environmental stimuli. This theory pays more attention to the influence of the external environment. Quick (1984) and other scholars, who support the reaction theory, emphasizes the need to study people's psychological responses to work stress. A more comprehensive overview of the work-related stress is given in stimulus-response theory. Robbins's "stress source-stress experience-stress result" has been widely used as a classical model in organizational work-related stress management.

Unsafe Behaviour

Unsafe behaviour in the construction industry refers to the behaviour of those who have caused an accident or may cause an accident, including two major connotations: First, it refers to the behaviour that has a high probability of causing an accident; second, it refers to the fact that it is not conducive to reducing disasters during an accident. Apparently, the "human" factor is highlighted in unsafe behaviour, which refers to the construction unit's operational personnel, such as construction workers and managers. Through investigation and analysis of safety accidents in the construction industry, Researchers have found that construction workers' unsafe behaviours are the direct cause of accidents

The common unsafe behaviours are divided into several categories. Different official organizations will use corresponding methods to classify unsafe behaviours. The ILO divides unsafe behaviours into six categories: 1) neglecting safety operations when supervisors are absent; 2) performing machine operations at inappropriate speeds; 3) illegally using equipment with unacceptable safety performance; 4) using Tools are not safe or methods are not safe; 5) dangerous decoration, cultivation, mixing and connection methods; 6) ignore safety attitude work in a dangerous environment. The categorization standard for casualties of official employees (GB6441-1986) published in China in 1986, divided human unsafe behaviours into 13 categories, 54 sub-categories, such as operational errors, failure of safety equipment, and use of unsafe equipment.

Due to the inherent characteristics of the construction industry, construction workers are inevitably do some unsafe behaviours. For example, Construction workers may not wear safety protection equipment, such as safety helmets and seat belts, while at the construction site. Construction workers did not follow the correct operating procedures for construction (Adnan Enshassi *et al*., 2015).

The traditional approach to evaluate construction workers' safety behaviours (CWSB) is through the measurement and statistical analysis of incident-related data (such as number of injuries and ill-health, accident frequency and severity rates, and accident costs), which are often referred to as retrospective or lagging indicators (Sgourou *et al*., 2010).

Robbins' Stress Model

The Robbins stress model is a relatively complete conceptual model that embodies job stress generation and has been widely used in organization work stress management. In his book, Robbins introduced the model in detail. He believes that the potential sources of stress can be divided into three categories: Environmental factors, organizational factors and personal factors. When individuals feel pressure, they will experience different pressure feelings due to their personal work experience, social support, and loyalty. Thus, they will eventually manifest the pressures in physical, psychological, and behavioural aspects (Robbins, 2012). The Robbins model is shown in Figure 1. According to this model, work-related stress resources involved in previous literature is shown in Table 1.

THEORETICAL HYPOTHESIS

According to the purpose, this paper further clarifies the research path on the basis of the literature review. That is, starting from the source of work-related stress in the construction industry and considering the entire transformation process from the source of work-related stress to unsafe behaviour. Taking into account the complexity

of work-related stress and unsafe behaviour, this paper needs to further refine the concept of these.

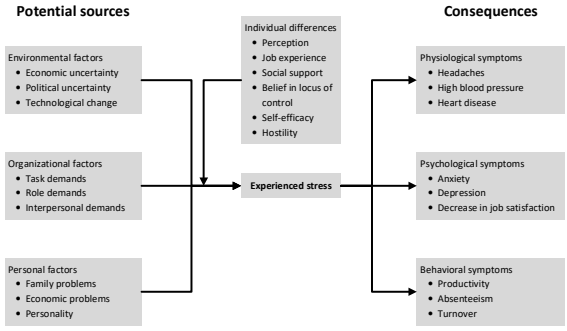

Figure 1: Robbins' Stress Model

Table 1: Relevant Factors on Work-related Stress Resources Involved in Previous Literature

	1993 Sutherland *et al.*,	1996 Gunning *et al.*,	2000 Madine	2003 Goldenhar *et al.*,	2006 CIOB	2007 HSE	2014 Paul Bowen
Environmental factors							
Lack of social support	√	—	—	—	—	√	√
Technological change	—	—	√	—	—	—	—
Job tenure	—	√	√	√	—	—	—
Organizational factors							
Conflict demand	—	√	—	√	√	—	√
Commuting	√	—	—	—	—	√	—
Work long hour	√	—	√	√	—	√	√
Deadline pressures	√	√	√	—	√	—	√
Volume of paperwork	√	—	—	—	—	—	—
Inadequate communication	√	—	—	—	—	—	—
Staff shortage	√	—	—	—	—	—	—
Job over control	√	—	√	√	—	√	√
Increasing competition	—	—	√	—	—	—	—
Organizational climate	—	—	—	√	—	—	√
Work overload	—	√	—	—	√	√	√
Personal factors							
Financial penalty clause	—	—	√	—	—	—	—
Conflict with the firm	—	√	—	—	—	—	—
Work-life balance	√	—	—	—	—	—	√

The research background of this paper is mainly based on Chinese construction projects and focuses more on stress source analysis, so work-related stress is defined as a series of reaction processes formed by individuals under the continuous action of stressors. Also, this article defines unsafe behaviour as the behaviour of those who may cause an accident. Thus, based on previous scholars' research, this paper proposes two theoretical hypotheses and validates them. H1: The severity of work stressors is positively related to the frequency of unsafe behaviour. H2: Different working pressure source structures have different conversion effects to unsafe behaviour. Based on this assumption, this paper compare the three main work stress theory. Considering the aim to analyse the entire transformation process from stressors to behavioural features, the Robbins model has a similar three-layer

structure. Therefore, the Robbins model is selected as the theoretical basis for Work-related stress transformation model in construction.

METHODOLOGY

Based on the above two related assumptions and the theoretical basis of the transformation model, the research method of this paper is divided into three steps, including the determination of transformation model, the collection of relevant data and the selection of data analysis methods.

Work-Related Stress Transformation Model in Construction

Based on Robbins model, this paper focus on the characteristics reflected in the behaviour and puts forward the work stress model for construction industry practitioners. It was found that there was a difference in the sources of pressure between the managers and the workers in construction industry. Among them, volume of paperwork, long way commuting, the shortage of staff and the lack of communication were sources of pressure unique to managers. At the same time, the unsafe behaviours studied in this paper are based on the project level, three common unsafe behaviours are selected, including not wear safety protection equipment, illegal construction, and not active participation in safety technology. Based on the previous analysis, the final model of the work-related stress transformation in the construction is put forward and shown in the following figure 2.

Data Collection Method

15 factory construction cases are selected as the database for project analysis. Through interviews and investigations with 15 on-site construction projects' safety managers, this paper quantifies the severity of pressure sources and the frequency of unsafe behaviour in 15 cases. Since stressors and unsafe behaviour cannot be directly measured, the 5-point scale method Likert was used to evaluate its severity.

Selection of Analysis Model

Data Envelopment Analysis (DEA) is a non-parametric method proposed by Charnes, Cooper, and Rhodes (CCR) in 1978, which aims to measure the relative production efficiency of multiple decision-making units (DMUs).

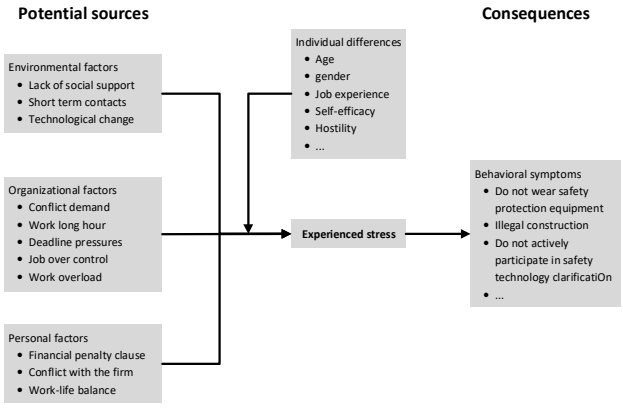

Figure 2: Stress transformation model in construction

Compared to the parametric approach, it can effectively evaluate the relative efficiency of multiple input and multiple output DMUs. The application of DEA has matured, but this maturity has not reached the same level in the field of construction. The first successful case of DEA applied by Charnes and Cooper *et al*., was to

evaluate the effect of setting up a public school for mentally handicapped children. In the assessment, the output includes intangible indicators such as "self-esteem". Each indicator has difficulty in setting weights. At the same time, the DEA model does not need to set the functional relationship between indicators in advance. According to the hypothesis, there is a correlation between the severity of work stressors and the frequency of unsafe behaviour. The article chooses a multi-index relationship analysis method and considers that the functional relationship between the two is unknown, and for the purpose of analysing the conversion efficiency, this paper believes that DEA has the ability to analyse the links between intangible indicators and the non-parametric analysis features are suitable for analysing the transformation model.

DATA ANALYSIS AND DISCUSSION

Analysis and Interpretation of Index

The DEA research model includes input variables as well as output variables. The choice of input and output indices is based on the principles of rationality, objectivity and credibility. The previous article sorted out the basic model of the construction industry's work-related stress transformation. The source types are merged and the final model input and output specifications are shown in Table 2. In order to facilitate further analysis, each index is represented by codes I1-I5 and O1-O3.

Table 2: System of Final Indexes

	Second tier indexes	Third tier indexes	Code
Input	Environmental factors	Lack of social support	I1
		Short job tenure	I2
		Conflict demand	I3
	Organizational factors	Deadline pressures	I4
		Job over control	I5
Output	Unsafe behaviour	The severity of illegal construction	O1
		The severity of construction without security facilities	O2
		The severity of negative participation in Safety technology clarification	O3

Analysis Using DEA Method

Data processing

Through interviews and investigations with 15 on-site factory construction cases' safety managers, this paper use the 5-point scale method Likert to quantify the severity of work stressors and the frequency of unsafe behaviour. At the same time, for the confidentiality of information, M1-M15 codes are used to represent the projects, which are located in Wuhan, Shanghai and Beijing. Small, medium and large projects are all involved. For data processing using the DEA method, a positive correlation between input and output variables is required. Before the DEA analysis, the correlation between input and output value is analysed, with the calculation results given in Table 3. The degree of correlation is calibrated using the coefficient γ.

$$-1 \le \gamma \le +1 \begin{cases} \gamma = -1, completely\ negative\ correlation; \\ -1 < \gamma < 0, negatively\ correlated \\ \gamma = 0, uncorrelated \\ -1 < \gamma < 0, negatively\ correlated \\ \gamma = 1, completely\ positive\ correlation \end{cases}$$

Table 3: Correlation Analysis for the Input and Output Index System

	I1	I2	I3	I4	I5
O1	0.8589	0.6593	07023	0.4859	0.5372
O2	0.5430	0.5322	0.6506	0.3174	0.2299
O3	0.2912	0.4846	0.6000	0.2933	0.2275

As can be seen from the Table 3, $0 < \gamma < 1$; this indicates a positive correlation between input and output. Based on the input data, the raw data were tested by correlation analysis for the input and output of the final index (Table 3) and were input into the Maxdea ultra7.0 software with the DEA analysis results of Construction Projects M1-M15 given in Table 4.

Table4: Analysis results of ineffective technical units

DMU	TE	Input improvement					Output improvement		
		I1	I2	I3	I4	I5	O1	O2	O3
M4	0.667	-33.3%	-33.3%	-45.8%	-66.7%	-33.3%	8.3%	8.3%	0.0%
M6	0.8	-20.0%	-20.0%	-33.3%	-60.0%	-60.0%	0.0%	100.0%	60.0%
M8	0.917	-8.33%	-8.33%	-8.33%	-36.7%	-43.3%	0.0%	66.7%	0.0%
M10	0.917	-8.33%	-8.33%	-8.33%	-20.8%	-20.8%	-29.2%	0.0%	0.0%
M11	0.833	-20.0%	-20.0%	-16.7%	-16.7%	-33.3%	0.0%	0.0%	0.0%
M14	0.875	-20.0%	-20.0%	-12.5%	-40.0%	-37.5%	0.0%	0.0%	0.0%
M15	0.889	-28.9%	-11.1%	-11.1%	-11.1%	-22.2%	0.0%	0.0%	0.0%
Mean	0.926	-9.3%	-8.1%	-9.1%	-16.8%	-17.3%	0.6%	11.7%	8.4%

DISCUSSION

According to the results of Correlation Analysis, the severity of work stressors is positively related to the frequency of unsafe behaviour. And based on the DEA analysis, the average efficiency of M1-M15 is 0.926, which means that the overall efficiency is relatively high. So, there is a situation in which the work-related stress actually shifts to unsafe behaviour. Among them, the integrated efficiency values of the eight decision units M1, M2, M3, M5, M7, M9, M12, and M13 are 1, which means the DMU is DEA effective and the work-related stressors structure indeed lead to insecurity behaviour. The efficiency values of M4, M6, M8, M10, M11, M14, and M15 are all less than 1, indicating that the efficiency is invalid, and the input-output structure is unreasonable. Since the model is based on the transformation of work-related stress into unsafe behaviour, it is necessary to analyse the causes of the invalid model and find the key factors that needs to be controlled.

In this paper, through the projection analysis, the radial improved value, the slack improved value and the target value of the non-DEA effective unit can be calculated, and then the input redundancies rate and the output insufficiency rate can be obtained, which can provide reference for how to avoid the conversion efficiency. Target value = original value + radial improvement value + slack improvement value, input/output improvement ratio = (target value - original value) / original value, and the absolute value of the input improvement ratio is the input redundancy rate, as shown in Table 4. From the input point of view, the input improvement ratio of I5 is -17.26%, and the input improvement ratio of I4 is -16.8%, indicating that the current I5 has a degree of redundancy of 17.26%, and I4 has a degree of redundancy of 16.8%.Firstly, from the analysis of cases characteristics, there are seven cases that have not been fully converted in the process from work-related stress sources to unsafe behaviour. The seven projects are all relatively medium-sized or large constructions, which means

that larger projects may have stronger control on work-related stress transformation. Secondly, from the perspective of the structure of the work stressors and the structure of the unsafe behaviour output, there is a large amount of redundancy in the severity of I5 (job over control) and I4 (Deadline pressures), but it does not cause the complete conversion to unsafe behaviour, which means that these two sources of stress may not directly lead to the transformation. We may pay more attention to the other three factors: Lack of social support, Short job tenure and Conflict demand. Some parts of the conclusion and former research in the literature are also in agreement. For example, scholars have begun to pay attention to the relationship between social support, work stress and unsafe behaviour. (Sampson *et al*., 2014, Chan *et al*., 2018).

CONCLUSIONS

Based on the Robbins' pressure model, this paper studies typical stressors and unsafe behaviours in the construction industry and proposes a work-related stress transformation model. The corresponding DEA model was constructed and 15 cases were used as the database to analyse the efficiency of the transformation. Through case analysis, common work-related stressors were identified and advices on pressure source control of on-site construction are provided. According to the literature review, Lack of social support, short term contacts, Change, conflict demand, work long hour, deadline pressures, job over control, work overload are eight common sources of on-site work pressure. Because there are only a limited number of cases that can be investigated, this paper only selects the five most frequently studied pressure sources for analysis and it leads to the following conclusions, and these conclusions may only apply to the factory construction: 1. There is indeed a shift from work-related stress to unsafe behaviour, and it is more convenient to control the conversion from the source of work-related stress. 2. The management of the work pressure transformation in the medium and large-scale engineering sites may be better than the smaller ones.3. The three factors of Lack of social support, Short job tenure and conflict demand all need attention in the process of the work-related stress transformation. On the contrary, Deadline pressure, which we often believe is the most important factor that causes work stress, is not plays the most critical role in the conversion process. Therefore, a more in-depth analysis of the sources of work stress plays a crucial role in the management of work stress.

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