The Study of Construction Worker Safety Analysis

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Abstract— **Construction industry is one the most unsafe and hazardous industries to work in. In India very less significance is given to construction safety and adding to that the Indian labour market is such that the status of safety in construction becomes even worse. In general, the Indian construction labour is poor, uneducated (sometimes even illiterate) and are not aware of the importance of safety procedures. They are also given the less importance by the management as far as safety is concerned and are always at disposal. All these factors influence the safety behaviour of the labour, leading to injuries and fatalities at construction sites. Therefore by assessing and controlling the safety behaviour of labours the rate of injuries and fatalities can be lowered.**
In this study we will try to understand the reasons for accident causation, the importance of safety behaviour and then figure out main factors that influence the labour safety behaviour. The scope of work is restricted to Indian construction industry. We will focus on high rise buildings, small construction enterprises and metro projects.
The assessment of the identified factors would be done by the statistical technique called Structure Equation Modelling (SEM). The application SEM would be done by the application software called Statistical Package for Social Sciences (SPSS) and Analysis of Moment Structure (AMOS).

I. INTRODUCTION

Construction industry by its inherent nature is the most hazardous industry, recording the highest accident rates worldwide. Unfortunately, the kind of construction workers (CWs) found in India **doesn't make it any safer.** Statistics from the International Labour Organization (ILO) reveal that there were 47000 deaths from occupational accidents in India in 2003. Globally, construction labour accounts for 7.5 per cent of the labour force and suffers 16.4 per cent of fatal occupational accidents. These figures are conservative as they do not include minor accidents, work-related illness and incidents. Moreover, there are several cases wherein the incidents/accidents are not reported to the authority or go unnoticed because of the lack of an authority (like in India). In UK, RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013) makes sure that the employers, the self-employed and those in control of premises to report specified workplace incidents.

Manuscript received April 14, 2016
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CWs refer to a group of frontline staff who contribute to the various work trades involved in various construction projects, including concrete work, machine and crane operation, plumbing and piping, painting, electrical work, and carpentry (Census and Statistic Department, HKSAR,

2009). They have direct impact over a project's outcome of time, cost and quality and are the
most valuable employee in a company *[Applebaum, 1999]*. Even after being of such significance in the company, they are placed at the lowest level and are most susceptible to illness, injuries and fatalities while working.

The implications of construction related injuries are not limited to human injuries but, it also has a huge economic impact. The number of work-days lost due to work-related ill health and work-place injuries is major setback for construction projects and causes huge time and cost overruns in it. The Health and Safety Executive (HSE) in its health and safety statistics 2013/14 of Britain reports a loss of 2.3 million working days in the year. In India, construction industry the second largest employer (after agriculture) and a major GDP contributor and hence it is important for important construction projects to finish on time and within stipulated budget.

NEED FOR RESEARCH

In India, construction safety is given the least importance and is merely limited to use of Personal Protective Equipment (PPE), sometimes not even that. The result of which is time and cost overruns, but the companies need to understand that more than time and money it is the life of CW that is of utmost importance. There are only a few companies in India that follow safety regulations and provide a safe environment to their frontline workers. Research has shown that such companies not only save a lot of money (by avoiding overruns), but also have less attrition rates of CWs, earn loyalty of CWs and project a good image in the market. Therefore, for a company to have such advantages, it is necessary for them to understand the importance of construction safety and reduce the number of accidents, injuries and fatalities. From all the previous mentioned theories of accident causation, it evident that people, humans, or workers are one of the major reason for construction accidents. As per HSE (2002), human behavior

contributes approximately 80% of the construction accidents. Garavan & O'Brien (2001), Hoyos
(1995), in their research also concluded that a majority of workplace accidents and injuries are attributed to the unsafe work practices of employees rather than unsafe working conditions.

OBJECTIVE:

The objective of my study is to identify the factor that influence the safety behaviour of CWs on construction sites and then correlate these factors to develop an accident causation model. The results of my research would help the construction companies in designing the CW job adequately, so that they do not overload or overstress the CW. It would also help the safety officers in making necessary safety arrangements where the CWs are more susceptible to make error. I tend to understand the CWs viewpoint as to why accidents happen on a construction site.

SCOPE OF WORK

1. The identification of the main factors that influence the safety behaviour of CW by studying the researches on behavioural science related to safety.
2. Interview the CW working in high rise construction, metro construction, small construction enterprises, etc and gather around 200 responses.
3. Analyse the collected data by using Statistical Package for Social Sciences (SPSS) and Analysis of Moment Structures (AMOS).
4. Suggest an accident causation model.

RESEARCH METHODOLOGY

The basic technique used in this study, for the assessment of work injury among construction workers is Structure Equation Modelling (SEM). The application of SEM can be done by using various application softwares like Linear Structure Relations (LISREL), Analysis of Moment Structures (AMOS), etc. This study uses AMOS, which is an added Statistical Package for Social Sciences (SPSS) module, for the SEM of work injury among construction workers.

IDENTIFICATION OF CONSTRUCTS

The main constructs identified as the drivers of construction accidents are Social Support, Work Hazards, Safety Environment, Job Stress, Job Dissatisfaction, Negative Personality and Safe Working Behavior. Social Support comes from management, supervisors and co-workers. Work Hazards are because of the physical conditions prevailing at site and the pressure that the CW has been put into for completing a task. Safety training, safety practices and the availability of personal protective equipment (PPE) contribute to a Safe Environment at site. Family responsibilities and excess work puts a CW into a lot of stress. Job Dissatisfaction mainly arises due to less salary, no chances of promotion and by performing repetitive work. The negative

features of a CW's personality like impulsivity, risk taking behaviour, pride and depression also

QUESTIONNAIRE DESIGN

The variables used for the design of questionnaire are management (2 questions), co-worker support (2 questions), job stress (3 questions), safety training (2 questions), safety practices (4 questions), PPE (2 questions), physical hazard (2 questions), impulsivity (2 questions), risk taking behavior (2 questions), pride (2 questions), depression (2 questions), supervisor support (2 questions), production pressure (1 questions), job dissatisfaction (4 questions), safety work behaviour (3 questions) and work injury (2 questions). All the above variables were measured on

5 point Likert scale (1-strongly disagree and 5-strongly agree). So there are a total of 37 questions and every question is represented as a variable in the research model. The variable representation is as follows-

1. Management- m1, m2
2. Co-worker support- cws1, cws2
3. Job stress- js1, js2
4. Safety training- st1, st2
5. Safety practices- sp1, sp2, sp3, sp4
6. Personal protection equipment- ppe1, ppe2
7. Physical Hazard- ph1, ph2
8. Impulsivity- i1, i2
9. Risk taking behavior- rtb1, rtb2
10. Pride- p1, p2
11. Depression- d1, d2
12. Supervisor support- sup1, sup2
13. Production pressure- pp1
14. Job dissatisfaction- jd1, jd2, jd3, jd4
15. Safety work behavior- swb1, swb2
16. Injury- fatal, nonfatal

DATA COLLECTION

A total of 172 samples were collected from the labours working at various construction sites in Delhi NCR. The samples were mainly collected from the construction sites of Delhi Metro, real estate projects of Experion Developer and DLF. In India most of the CWs are not educated as a consequence they are not able to read and write. The questionnaire was in English language and thus the responses were noted by reading out the questions to the CWs in Hindi language. Out of 172 samples that were collected 98 (57%) claimed to have not suffered any kind of injury while working while the remaining 74 (43%) were involved in some kind of fatal or non fatal accident that resulted in an injury.

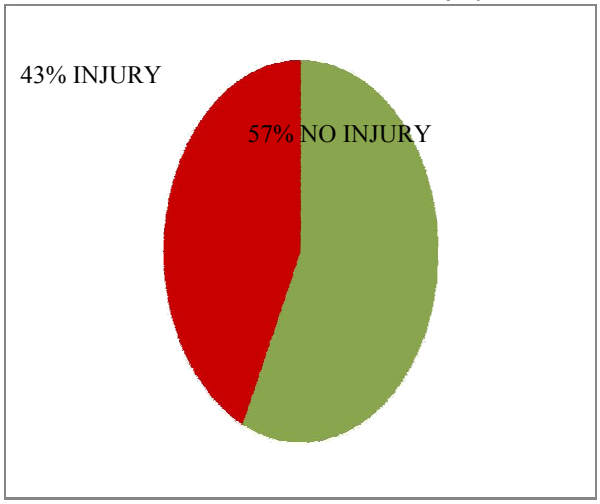


Figure 3-4: Classification of responses based on work injury

VALIDITY AND RELIABILITY ANALYSIS

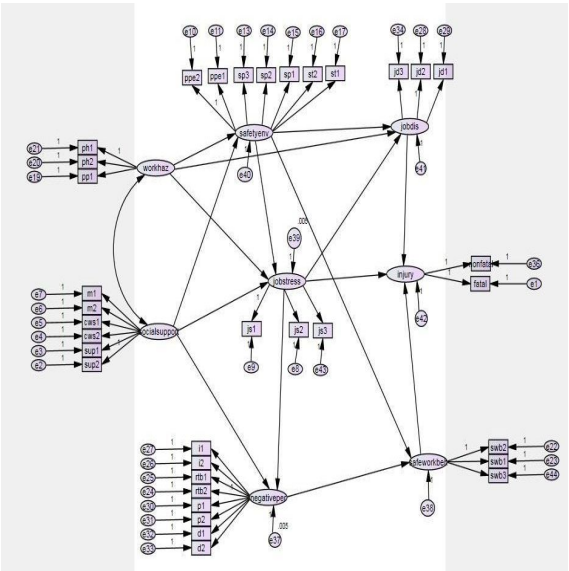
The quality of data collected can be assessed by checking its validity and reliability. Validity is the quality of a measure being an adequate and acceptable of what it is supposed to represent. There are six forms of validity; Face validity, Criterion validity, Construct validity, Content validity, Internal validity and External validity. This research only verifies the Content validity of the questionnaire. Reliability addresses the question of whether a particular technique or survey question would yield the same result each time. It

checks the homogeneity of the items in a questionnaire. There are again several methods for measuring reliability like Test-Retest, Inter-Rater, etc, but the most common method is by checking the internal consistency of the questionnaire responses. Therefore, the internal consistency for the collected data was measured by using the Cronbach Alpha test in SPSS. Alpha value of 0.7 is considered good but in exploratory studies Alpha value of 0.6 is also acceptable.

Initially when all the variables were taken into consideration the alpha value came out to be 0.602. While performing Cronbach Alpha test on SPSS it gives us an option to the scale the alpha value if any of the variables is deleted. The results of scaling showed that after deleting the variable jd4 (measures job dissatisfaction) the alpha value increased to 0.719 and successively after deleting the variable sp4 (measures safety practices) the alpha value further increased to 0.798 thus giving us a more reliable data. Therefore, the two variables jd4 and sp4 measuring job dissatisfaction and safety practices respectively were removed in succession. Firstly, jd4 was removed and then sp4 was removed after which alpha value of 0.798 was obtained. Removal of the two variables did not affect the validity of the model because even thought jd4 and sp4 are removed there still remain enough variables to measure their respective factors of job dissatisfaction and safety environment. Note that while working in AMOS a minimum of 3 manifest variables or indicator variables are required to measure a latent variable or factors.

STRUCTURAL MODEL

After all the latent variables are successfully estimated from the observed variables in the measurement model a structural model is proposed to check the relationship between the latent variables. Generally a number of structural models are proposed and the one with the best fit as the final structural model. For this project an accident causation model proposed by P. S. Paul and J. Maiti (2008) was taken as reference. After making certain modifications depending upon the current study the accident causation model that was proposed is shown in fig 4-3 and yielded a reasonable fit to the data.



DIRECT EFFECTS

The direct effect of exogenous variable social support on that of safety environment was found to be significant (path estimate = 0.89) and its negative impact on negative personality (path estimate = 0.25) was also considerable. Work hazard showed a positive significant effect on job dissatisfaction (path estimate = 0.27) and job stress (path estimate = 0.92) but its showed insignificant negative impact on safety environment (path estimate = -0.11). Safety environment directly influences safe working behavior (path estimate = 0.57) and decreases both job dissatisfaction (path estimate = -.033) significantly and job stress (path estimate = -0.13) insignificantly. Job stress shows positive significant relationship with job dissatisfaction (path estimate = 0.39), negative personality (path estimate = 0.75) and work injury (path estimate = 0.35). Negative personality shows negative impact on safe work behaviour (path estimate = - 0.42). Job dissatisfaction shows high positive impact on work injury (path estimate = 0.67). The direct relationship between safe work behavior and work injury can out to be insignificant in the analysis.

INDIRECT EFFECTS

Apart from direct influences the latent variables (exogenous and endogenous) have indirect influences over work injury as well. The indirect impact of exogenous latent variable social support can be seen through the following linkages-

social support□negative personality□safe work behavior□injury
social support□job stress□negative personality□safe work behavior□injury
social support□job stress□job dissatisfaction□injury
social support□job stress□injury
social support□safety environment□job stress□negative personality□safe work behavior□ injury
social support□safety environment□job stress□job dissatisfaction□injury
social support□safety environment□job dissatisfaction□injury
social support□safety environment□job stress□injury

The indirect impact of exogenous latent variable work hazard can be seen through the following

linkages-
work hazards□safety environment□job dissatisfaction□injury
work hazards□safety environment□safe work behaviour□injury
work hazards□safety environment□job stress□job dissatisfaction□ injury
work hazards□safety environment□job stress□negative personality□safe work behaviour□injury
work hazards□safety environment□job stress□injury
work hazards□job stress□negative personality□safe work behaviour□injury
work hazards□job stress□job dissatisfaction□injury

The indirect impact of endogenous latent variable safety environment can be seen through the following linkages-

1. safety environment□job stress□negative personality□safe work behaviour□ injury
afety environment□job stress□job dissatisfaction□injury
safety environment□job dissatisfaction□injury
safety environment□job stress□injury

The indirect impact of endogenous latent variable job stress can be seen through the following linkages-
job stress□negative personality□safe work behavior□injury
job stress□job dissatisfaction□injury

Latent endogenous variable negative personality has only one indirect linkage to injury i.e. negative personality□safe work behavior□injury. Latent endogenous variables job dissatisfaction and safe work behavior has only direct impacts over work injury and these impacts are already mentioned above. Indirect effect is computed by multiplying all the path estimates in the given path and then adding the estimates of all the specified paths for a given variable. For example the indirect effect of social support on injury is computed as follows-

social support□negative personality□safe work behavior□injury = -0.25 * -0.42 * 0.04 = $4.2 * 10^{-3}$
social support□job stress□negative personality□safe work behavior□injury = -0.05 * 0.75 * -0.42 * 0.04 = $6.3 * 10^{-4}$
social support□job stress□job dissatisfaction□injury = -0.05 * 0.39 * 0.67 = 0.013065
social support□job stress□injury = 0.05 * 0.35 = 0.0175
social support□safety environment□job stress□negative personality□safe work behavior□ injury = 0.89 * -0.13 * 0.75 * -0.42 * 0.04 = $1.457 * 10^{-3}$
social support□safety environment□job stress□job dissatisfaction□injury = 0.89 * - 0.13 * 0.39 * 0.67 = -0.03023
social support□safety environment□job dissatisfaction□injury = 0.89 * -0.33 * 0.67 = - 0.196779
social support□safety environment□job stress□injury = 0.89 * -0.13 * 0.35 = - 0.040495 total indirect effect = path estimate 1. + path estimate 2. + path estimate 3. + path estimate 4. + path estimate 5. + path estimate 6. + path estimate 7. + path estimate 8. = (-0.23)

Similarly the indirect effect on injury due to work hazard is (+0.223), due to safety environment is (-0.299) and due to job stress is (+0.249).
TOTAL EFFECT
The total effect of the latent variables on work injury is the sum of the direct effects and indirect effects. The direct, indirect and total effects of all the latent variables on work injury are shown in table 4-10.

Table 4-10: Total effects of latent variables on work injury

Latent Variables	**Direct Effect**	**Indirect Effect**	**Total Effect**	**Rank Order**
Work hazard	-	0.223	0.223	5
Social support	-	-0.23	-0.23	4
Safety environment	-	-0.299	-0.299	3
Job dissatisfaction	0.67	-	0.67	1
Safe work behavior	0.04	-	0.04	6
Job stress	0.35	0.249	0.599	2
Negative personality	-	-0.0168	-0.0168	7

As it can be seen from the table 4-5 job dissatisfaction has the highest effect (0.67) on work injury of construction workers. On second spot is job stress having a high positive effect (0.599) on work injury of construction workers. Social support (-0.23) and safety environment (-0.299) tend to reduce the work injuries while work hazard show positive impact (0.223) on it. In the analysis performed safe work behavior of the construction worker seems show negligible

impact (0.04) on their work injuries. Negative personality shows the least negative (-0.0168) on impact on work injury.

RESULTS

The result of the structural model or accident causation model shows that job dissatisfaction, job stress, social support, safety environment and work hazards are main reasons responsible for causing work injuries to construction workers working on sites under study. The latent variable work hazard has significant positive relation with job stress and job dissatisfaction. This means that construction workers (CWs) exposed to dangerous physical hazards and production pressure are under a lot of stress while performing their jobs and are also dissatisfied with their jobs. Hence companies must take measures to minimize these work hazards so that CWs are able work safely and satisfactorily. The latent variable work hazard also has a negative relation with safety environment but is insignificant due to path estimate value.

Social support shows a high positive impact on safety environment and show reasonable negative impact on negative personality directly and on work injury indirectly. Social support is given to the CWs by the management, co-workers and supervisors. Less is the social support, less safe is the work environment, which causes to job dissatisfaction to the CWs and lead to work injury. Poor social support also causes a person to become negatively personified directly and indirectly by increasing the job stress. A negative person indulges in more unsafe working behavior during their jobs. A healthy social environment at construction site can reduce job dissatisfaction and job stress among CWs thus reducing their susceptibility to work injuries. A good social support also improves the safe work behavior of the CWs by reducing their negative personality and job stress.

Safety environment though does not have any direct impact on work injury it still has significant indirect impact on work injury. Social support contributes to safety environment which in turn reduces the job stress and job dissatisfaction of CWs thus reducing their work injury. A safe working environment also impacts safe work behavior directly and indirectly by reducing the job stress and negative personality.

Job stress has significant direct and indirect impact on work injury. It can be seen from the structural model that job dissatisfaction increases work injury so, job stress increases the job
dissatisfaction of the CWs thereby increasing work injuries. It can also be seen that job stress increases the negative personality of the CWs thus encouraging him to get involved in unsafe work practices. But negative personality if CW does not have any significant direct or indirect impact on work injury even though it influences safe work behavior.

From the measurement model in fig 5-2 it can be seen that variable social support is measured by six indicator variable that ask question about management, co-worker support and supervisor. All the indicator variables are strongly related with social support. Therefore the results indicated that with good management, co-worker interaction and supervision the social support can be improved at the construction site. The indicator variables of latent variable safety environment also show high relation with it thus indicating that the injured workers are not satisfied with existing safety training methods, safety practices and safety equipment.

Therefore it can be concluded that job stress and job dissatisfaction are the major reasons and social support, work hazard and safety environment are strong predictors of work injuries among CWs. Job stress and job dissatisfaction among CWs arise due to unsafe working environment, fierce work hazards, poor social support and by excess repetitive work.

CONCLUSION

Structure Equation Modelling (SEM) is a complex technique that is used to explain relationship among variables. It is a combination of various techniques like multiple regression, factor analysis, etc. Analysis of Moment Structure (AMOS) is a graphical software tool distributed by SPSS which was designed to make SEM analysis easier. SEM consists of a measurement model and structural model. In the measurement model relationship between latent variables and their indicator variables is estimated by using Confirmatory Factor Analysis (CFA). In structural model the relationship among the measured variables or latent variables is established by path analysis.

An accident causation model was developed to estimate the safety performance of construction workers (CWs) and the application of this model was confirmed by using a case study which involved responses from CWs working at Delhi metro projects and some high rise construction projects in Delhi NCR. The results of the case study showed relationship among the various factors responsible for causing accidents at construction sites. The results of the structural model show that job stress and job dissatisfaction are the major reasons contributing to work injuries at construction sites. Social support, safety environment and work hazards have direct effects on job stress and job dissatisfaction thus they indirectly influence the work injuries of construction workers.

Work hazards are due to tough physical environment that the construction workers are subjected on site and unpractical production pressures put on them by the management. Moreover these hazards also increase the job stress and job dissatisfaction of CWs. Work hazards at construction sites can be moderated by (1) proper hazard identification by regular inspection (2) removal of the identified hazards (3) maintaining an easy working schedule. Social support to the CWs is given by the management, co-workers and supervisor. Better social support on one hand will improve the safety environment and on the other it will reduce job stress and negative personality in CWs. Therefore social support can indirectly reduce the work injury among CWs.

A good or bad safety environment can be a consequence of work hazard and social support and then can go on to influence job stress and job dissatisfaction directly and safe work behavior directly and indirectly, thus influencing work injury of construction workers. Safety environment at the construction site can be improved by (1) insuring adequate supply and maintenance of personal protection equipment (PPE) (2) forming a safety committee that ensures everyone follows safety rules on site, regularly conduct safety meetings and give safety rewards

(3) develop new and modern methods of safety training. Negative personality of the CWs is a result of job stress and can be reduced by providing a good social support to them. Although in the study negative personality shows no significant direct or indirect impact on work injury, it still has significant direct relation with safe work behavior. Impulsivity, risk taking behavior, pride and depression constitute the negative personality of the construction worker. Negative personality of the CWs can be suppressed by (1) proper training (2) counseling and psychological treatment (3) imposing fines on display of negative characteristics (4) giving rewards for good personal behavior.

In this study job stress and job dissatisfaction were found to be as the major reasons responsible for causing work injuries in construction workers. Job stress is a consequence of work hazard, social support and safety environment and influences the work injury directly and indirectly. Bad safety environment, increased work hazards and job stress contribute to job dissatisfaction. Job dissatisfaction shows a direct positive impact over work injury. Since job stress and job dissatisfaction show a positive relation both can be reduced by improving the safety environment, reducing the work hazards and increasing the social support to the construction workers.

ACKNOWLEDGEMENT

I would like to thank Dr. Arvind Dewangan – Professor & HOD , Civil Engg Deptt (Construction Technology & Management), HCTM Technical Campus Kaithal, Haryana,for his sincere, continuous efforts and for his valuable suggestions.

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