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Construction Job Safety Analysis

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ABSTRACT

Job Safety Analysis (JSA), which is also known as Job Hazard Analysis, is an efficient proactive measure for safety risk assessment used in industrial manufacturing settings. However, unlike the manufacturing settings for which JSA was developed, at construction sites the physical environment is constantly changing, workers move through the site in the course of their work, and they are often endangered by activities performed by other teams. To address this difficulty, a structured method for hazard analysis and assessment for construction activities, called "Construction Job Safety Analysis" (CJSA), was developed. The method was developed within the framework of research toward a lean approach to safety management in construction, which required the ability to predict fluctuating safety risk levels in order to support safety conscious planning and pulling of safety management efforts to the places and times where they are most effective. The method involves identification of potential loss-of-control events for detailed stages of the activities commonly performed in construction, and assessment of the probability of occurrence for each event identified. It was applied to explore 14 primary construction activities in an extensive trial implementation that included expert workshops and a series of 101 interviews with site engineers and superintendents. Detailed quantitative results were obtained for a total of 699 possible loss-of-control events; the most frequent events are those related to exterior work at height.

1. Introduction

Identifying and assessing the hazards and risks is an essential step in safety management (Brown, 1976; Goetsch, 1996; Holt, 2001). Job Safety Analysis (JSA), also known as Job Hazard Analysis (JHA), is a practical method for identifying, evaluating and controlling risks in industrial procedures (Chao and Henshaw, 2002). However, the differences between construction sites and manufacturing facilities give rise to the need for a specialized method for construction.

Construction projects are dynamic (Bobick, 2004). They are characterized by many unique factors – such as frequent work team rotations, exposure to weather conditions, high proportions of unskilled and temporary workers. Construction sites, unlike other production facilities, undergo changes in topography, topology and work conditions throughout the duration of the projects. These features make managing construction site-safety more difficult than managing safety in manufacturing plants. Particularly in construction, a different approach is needed to identify hazards and risks, increase safety and prevent accidents.

Previous studies have analyzed accident causation in construction, for modeling risk assessment and for accident prevention in construction sites. Mitropoulos et al. (2003) suggested an accident causation theory based on the observation that the organizational pressure to increase productivity and the individual worker's natural drive to minimize effort pushes workers to work near the edge of safe performance. Ale et al. (2008) developed and tested a tool for accident analysis based on a story-builder method which improves investigation and categorization of accidents.

The specialized method presented here is called 'Construction Job Safety Analysis' (CJSA). It is tailored to collect detailed information about any specific set of construction methods, and its end product is a database of the likelihood of occurrence of loss-of-control events. The database is suitable for use with contextual information about any individual construction project to evaluate the likelihood of exposure to various accident scenarios that can arise through the execution of the project.

1.1. The CHASTE approach

In almost every country in the world, the construction industry stands out among all other industries with disproportionate numbers of severe and fatal accidents (Ahmed et al., 2000; Findley et al.,

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2004; Gyi et al., 1999; Hinze, 2008; Kartam and Bouz, 1998; Shepherd et al., 2000).

Applying lean thinking (Womack and Jones, 2003) to construction in this context leads to the hypothesis that, like production control itself, activities to enhance safety should be pulled by current system needs rather than pushed uniformly onto workers and activities. The CHASTE (Construction Hazard Assessment with Spatial and Temporal Exposure) approach has been developed in a research project for the Preventive Action Unit of the Industrial Labor Inspector's office of the Israel Ministry of Labor (Rozenfeld et al., 2009). The basic idea of the CHASTE is that although construction projects as a whole are unique and dynamic, individual construction tasks and methods are fairly well-defined and expected. For example – pouring concrete using a crane on site is a common well understood trade activity, but the level of risk associated with it can differ depending on its context. At one site, it may be performed at the end of the day when no other tasks are being performed, while at another, it might be performed at the middle of the day when many other workers are located either on or below the element being cast.

By separating the potential for loss-of-control from the potential for presence of victims, it becomes possible to compute a time-dependent risk level forecast, using a database of probabilities of loss-of-control for standard work methods, coupled with site-specific computation of workers' exposure to possible loss-of-control events. The result is a more accurate assessment of actual risks than is available using current methods, such as Preliminary Hazard Analysis (PHA) (Elzarka et al., 1995; Hansen, 1993; Saurin et al., 2004) which disregards the exposure factor. The predicted risk levels can be computed for various planning windows, and used either to pull safety interventions or to change production plans, both of which enhance safety. Thus management efforts to enhance safety can be less wasteful and more effective.

A statistical approach based on historic accident data is unsuitable for computing the risk levels needed in the trade method risk database for two main reasons. Firstly, the CHASTE approach considers location, exposure to other teams, work method, and personal factors to assess risk levels, producing very large combinatorial number of possible accident scenarios. The number of documented accidents is many orders of magnitude smaller than the number of potential accident scenarios, so that for most scenarios, the sample size of accidents recorded would be zero or too small to be considered statistically significant. Secondly, we are concerned with the probability of loss-of-control while performing a task rather than with the probability of an accident occurring. For every serious construction accident, there are multiple actual dangerous events (near misses) that end with no injury (Shapira and Lyachin, 2008); these should be taken into account when assessing loss-of-control risk levels, but the vast majority are not recorded and do not appear in statistical records. Hence, an approach based on aggregated accident statistics is not suitable and cannot be used to build a database useful for assessing the likelihood of loss-of-control events at any particular place during any particular time frame on a construction site.

To overcome this problem, a different conceptual approach was adopted in the development of CHASTE. Instead of assessing risk as a function of likelihood of an accident and its potential severity (two parameters), the risk level was divided into three parameters:

1. The probability of a loss-of-control event occurring.
2. The exposure of potential victims in time and in space.
3. The likely severity level of an accident (which is also dependent on the use of personal safety gear).

The fundamental change is that accidents are replaced by loss-of-control events and the potential for any victim to be exposed to them. To implement this in practice requires knowledge of construction activity types, including the nature and probability of loss-of-control events, the impact of environmental intensifying factors, the use of protective gear, and the potential severity of accident scenarios. Each of these must be compiled in a knowledge base in a form that can be used by software that implements the CHASTE approach to compute risk levels for specific construction projects. The CJSA method was devised to collect this knowledge.

1.2. Job Safety Analysis

The process of JSA includes three main stages (Chao and Henshaw, 2002):

(1) Identification – choosing a specific job or activity and breaking it down into a sequence of stages, and then, identifying all possible loss-of-control incident that may occur during the work.
(2) Assessment – evaluating the relative level of risk for all the identified incidents.
(3) Action – controlling the risk by taking sufficient measures to reduce or eliminate it.

For determining a priority order of treatment, the level of each incident risk is evaluated by assessing the incident's probability of occurrence and its expected outcome (the level of injury). Those two measures place the risk in a standard scale from most negligible to the most severe.

In essence, the JSA method has proven to be effective for planning the safest way to perform a task (Holt, 2001). However, in its current form, it is impractical for the construction industry. Unlike other industries, construction projects are highly dynamic; the production environment changes in time and place, and work crews change frequently. Moreover, construction products are unique, and are almost always prototypical; standardized procedures that may be considered safe in one project may be hazardous in the environment of a different project. Another drawback of the traditional JSA is that in construction, workers commonly endanger other workers, who may be performing a different activity at a different location. The standard JSA method is not designed to reveal these dangers since it focuses on production activities in isolation, at predetermined workstations. For these reasons, a different method is needed for construction in general, and to support the CHASTE approach in particular. This research proposes an improved technique, called Construction Job Safety Analysis (CJSA), in which the job analysis is performed independently of any specific consideration of time and place. This is achieved by separating the loss-of-control that precedes any accident from the potential presence of a victim in the path of harm. Loss-of-control events are assessed in the CJSA, which is generic across any local construction industry, while exposure of potential victims in time and space is assessed for specific construction projects.

2. CJSA process

The Construction Job Safety Analysis (CJSA) method generates a large knowledge-base describing all possible loss-of-control events in construction. The knowledge is structured in a form that can be used by software implementing the CHASTE approach to compute the predicted levels of risk for the activities of specific projects, by using a three-dimensional building model and a construction schedule.