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.,...
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.
The CJSA process comprises three major steps:

- **Step 1**: identify hazards – identify the set of direct and supporting construction activities needed for a domain, define their procedures, and analyze all possible loss-of-control events that may occur during their execution.
- **Step 2**: assess probability – evaluate the likelihood of occurrence of each loss-of-control event, the levels of possible intensifying factors, and the likelihood of use of personal safety gear.
- **Step 3**: assess severity – associate the possible loss-of-control events with possible accident scenarios, and assess the expected degree of severity for each type of accident scenario.

### 2.1. CJSA step 1 – Identification

The first step of the CJSA process is performed in a set of workshops in which the researchers interview experts in the execution of construction activities, usually senior construction superintendents. The activities relevant to the domain being explored (e.g. ‘multistory residential construction’) are identified, and each expert is asked to analyze one or more activities with which they are familiar. The procedure is detailed in Fig. 1, and an example of the activity breakdown structure is shown, together with an example, in Fig. 2.

The experts begin by dividing each activity into sub-activities. They determine the start and finish times of each sub-activity in relation to the overall activity duration as it would be defined in a construction plan. Values are set as percentages of the planned duration (activity start = 0%, activity end = 100%). In some cases, sub-activities may begin before 0% of the activity (e.g. preparation of scaffolding), and some may end after 100% of the activity (e.g. curing concrete, clearing formwork).

Next, each sub-activity is divided into work stages. The likely composition of the work teams and their expected locations while performing the task are detailed. Each stage may involve work at a primary location (usually defined in a construction plan) and at secondary locations, such as storage or loading areas. It is unreasonable to set fixed relative periods for the stages at this level of detail, and they may be repetitive, thus only the proportions of their durations within the sub-activities need be recorded.

### 2.2. CJSA step 2 – Assessment

The second step of the CJSA procedure seeks to determine the following information about the activities that were detailed in the first step:

1. The expected rate of occurrence for each possible loss-of-control event.
2. The degree of influence of the different managerial and environmental factors that affect the expected rates of occurrence.
3. The expected degree of use of personal safety gear.

Fig. 3 provides a flow chart for this step. The information is collected by means of an extensive survey that is conducted through face to face interviews with construction superintendents. The survey instrument is a set of structured questionnaires, one for each activity type. The questionnaires can be produced automatically from the database of activities, sub-activities, stages, typical loss-of-control events that may occur during each working stage of the activity, regardless of their likelihood.

Finally, the researchers compile a set of accident scenario types (Table 1), and match each loss-of-control event recorded with one or more types. Association with accident types is needed so that the potential victims of each loss-of-control event can be identified when a project’s risk levels are calculated. For any accident scenario type, workers who are adjacent to the loss-of-control event, below it, and/or above it may be exposed to the hazard. For some types, only the workers performing the activity in question are exposed – these are classified as ‘self impacting only’. The third column of Table 1 provides these logical relationships.

In order to classify the accident scenario types, it must be possible to calculate the level of exposure for each type as a function of the geometric relationships between the locations and any equipment involved. This requires a unique algorithm for each class of accident types. The necessary exposure algorithms have been developed and their application has been tested. Details can be found in Sacks et al. (2009).
of-control events, and their associated data, that was compiled in step 1.

The survey is conducted among construction superintendents because they are the most appropriate source for practical information about potential loss-of-control events. Firstly, due to their key role in the practical execution of the work, they, more than anybody else, are aware of the overall circumstances on site: the composition of activities on site and their nature, the types of activities, the number of workers involved, equipment in use, organizational conditions, etc. Secondly, they are formally responsible for all safety issues on site and are involved in the investigations that follow any incidents, whether accidents or near misses.

Every respondent is asked to assess the frequency of all loss-of-control event occurrences for the activity or activities in which they are most experienced. Two probability values are solicited for each loss-of-control event: both a numeric and a descriptive estimate of its likelihood (the dual values enable identification of unreliable responses). The numeric response consists of two values: a number and the appropriate unit of time (for example: three times a month, once a year, twice a week, etc.). The descriptive response offers a Likert scale with values from 1 to 5 (1 – has never occurred in my experience but is technically possible; 2 – occurs rarely, 3 – occurs seldom, 4 – occurs frequently, and 5 – occurs daily).

Many factors affect the safety level directly and indirectly, and they vary from one site to another. They include the nature of safety training on the job-site, the company’s safety culture, use of safety equipment, conditions of the work environment, weather, workers’ experience, work-load pressure, and more. Researchers have tested the influence of specific factors, or groups of factors,
on the rate of the accident occurrence (e.g. Hide et al. (2003) who examined the influence of causal factors on 100 documented accidents, and Hinzé and Raboud (1988) who found a relationship between project’s attributes and safety performance). A summary report of all claims for compensation from construction work related accidents (Bar et al., 2005) revealed significant tendencies of factors affecting accident rates. For example, it showed that construction workers were most likely to be injured on the first working day of the week, and that the number of days of absence tended to decrease as company size increased. Some factors, such as personal risk aversion, personal discipline, schedule delays and others, are difficult to monitor, and so are not of practical use in predicting risk levels.

The CJSA method acknowledges the importance of these factors and their integration in any application of the CHASTE approach. In the trial implementation described below, four specific factors (schedule delays; a work group’s first day on site; crowding of workers in the work area; and short notice before work begins) were tested for because they were of particular interest for research of the application of Lean Construction on the site in which the CHASTE method was implemented. Future users of the CJSA method should select factors relevant to the context of their industry in order to increase the reliability of the model.

Although these factors are collected, a word of caution is needed: little empirical evidence is available to calibrate their impact, and the professional literature does not provide indications of the potential correlations between these and other factors.

The final aspect tested for in step 2 of CJSA is the expected degree of use of personal safety gear during each particular activity, including helmets, appropriate working shoes, gloves, safety harnesses, and safety goggles. This information is needed for the CHASTE model, because the model assumes that the degree of severity of injury resulting from any possible accident will be distributed differently depending on the potential victim’s use of personal safety gear. The expected severity outcome for any event is the weighted average of the two severity distributions that result when safety gear is used and when it is not. In the questionnaire, every respondent is asked to assess the expected level of use of relevant personal safety gear by the workers in each production stage. This information reflects the sample population; during implementation for any particular project, a safety manager can adjust the levels of expected use of safety gear to local conditions.

### 2.3. CJSA step 3 – Assess Severity

The final step of the CJSA method determines the relative probabilities of severity for each accident scenario type. The distributions are obtained by asking safety expert interviewees to distribute the likelihood of the severity of the outcome for each type among four distinct possible outcomes:

1. Minor injury (up to one day of absence) – scratch, wound.
4. Death.

For each of these four possible outcomes, the expert assesses its likelihood relative to the other possible outcomes, as a percentage part, so that the cumulative likelihood of all the possible outcomes for a single event is 100%. Two distributions are assessed for each type; one assuming use of personal safety gear and the other assuming absence of the appropriate gear. The assessment is based on the assessor’s professional experience.

The distributions are used in the CHASTE approach to calculate a single severity level, which is multiplied by the likelihood of loss-of-control and the exposure levels for each event in order to calculate an overall risk level estimate. To transform the severity distributions into single weighted values, a set of weighting factors must be applied to the severity levels, which express the relative importance a risk assessor attributes to death, say, in relation to other injuries. This is a value judgment, which must be made by the end user. An example of four possible weight values can be seen in the second column, “Severity weight”, of Table 2. In this example, the user determined a scale for severity from 1 (for the lowest level) to 100 (for the highest), and set intermediate values of 5 and 25 for levels 2 and 3 respectively.

The example provided in Table 2 illustrates the overall procedure used for setting the expected severity level for the case of an accident scenario “falling from over 5 m height” while “casting concrete for exterior walls using industrialized forms”. The values that derive from step 2 of the CJSA survey appear in the “Expected occurrence” column. Two distributions are provided, reflecting the likelihood of occurrence of each outcome dependent on the use or non-use of personal safety gear (a safety harness in this case). The likelihood of use is 33%, and of non-use is 67%. The resulting weighted severity level is 52.6 (out of maximum possible value of 100).

### 3. Trial implementation

The CJSA method was developed and first applied in practice within the framework of the CHASTE research project. The scope for this implementation covered 14 common construction activities from all phases of a typical multi-story building project.

#### 3.1. Step 1 – Identification

In step 1, the knowledge was elicited in a series of workshops with safety experts and senior site managers, who are legally responsible for site-safety. Each expert was asked to analyze a single construction activity according to his or her experience.

Table 3 lists the range of activities covered with details of the number of work stages and loss-of-control events that were identified for each activity. After sorting, filtering and dismissing overlapping data, 699 different possible loss-of-control events were defined for 14 construction activities, out of the 875 loss-of-control events enumerated in Table 3.

<table>
<thead>
<tr>
<th>Severity level</th>
<th>Severity weight</th>
<th>Expected occurrence (%)</th>
<th>Weighted average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Minor injury</td>
<td>1</td>
<td>79</td>
<td>0.3</td>
</tr>
<tr>
<td>2) Medium injury</td>
<td>5</td>
<td>17</td>
<td>0.5</td>
</tr>
<tr>
<td>3) Severe injury</td>
<td>25</td>
<td>4</td>
<td>4.2</td>
</tr>
<tr>
<td>4) Death</td>
<td>100</td>
<td>0</td>
<td>47.6</td>
</tr>
<tr>
<td>Severity level</td>
<td></td>
<td></td>
<td>52.6</td>
</tr>
</tbody>
</table>
3.2. Step 2 – Assessment

The population for the survey in step 2 consisted of 91 senior superintendents from 45 construction companies. The majority were interviewed in depth about a single construction activity type. A small number of them were interviewed twice, because they were familiar with more than one activity type; a total of 101 interviews were conducted. The questionnaires were filtered by comparing the separate descriptive and numeric responses of each interviewee to the same questions, and by examining whether the responses were logical and complete. Of the 101 interviews, 14 were rejected due to inconsistencies that indicated misunderstanding of the questionnaire, leaving 87 valid complete questionnaires.

The respondents’ average period of construction experience was 21.8 years. In terms of company size, 44% were employed in small firms (up to 50 employees), 26% in medium-sized firms (51–200 employees), and 30% worked for large firms (over 201 employees). 7% of the respondents were working on small projects (up to 1500 m²), 61% on medium-sized projects (1500–7500 m²), 21% on medium-large projects (7500–15,000 m²), and 11% worked on large projects (over 15,000 m²).

3.2.1. Likelihood of loss-of-control event occurrences

Average values for likelihood of occurrence for all loss-of-control events were summarized in measures of number of events per year of work per person, i.e. the expected number of times a single event might occur, if a single worker performs a single task for a time period of one year. Table 4 lists five sample events out of the total 699 events that could arise from the 14 construction activities covered in the survey. The table includes the most frequent and the most infrequent events.

The knowledge elicited from the expert workshops (in step 1) included data describing the proportional duration of every work stage for each sub-activity. In any given construction project, the planned start and finish times for the sub-activities can be obtained from the schedule, and so the expected duration of each work stage can be determined. Multiplying the duration of a stage by the average event frequency and the number of workers in the work group gives the number of event occurrences expected for the stage during any period of activity.

To compare the results of the survey between different activities and types of events, the likelihood of occurrence was calculated for all loss-of-control events as if each one of the 14 activities was being performed continuously for one year, and the work stage duration was set respectively. The expected number of events for each activity is shown in Fig. 4. The most hazardous activity in terms of expected number of event occurrences is the application of exterior stucco, with 704 expected event occurrences for a single worker over a year (this is equivalent to a single plasterer causing an average of more than three loss-of-control

### Table 3
Activity analysis summary.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Interviewee specialization</th>
<th>Number of stages</th>
<th>Number of loss-of-control events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations</td>
<td>Piling</td>
<td>Superintendent</td>
<td>23</td>
</tr>
<tr>
<td>Structural activities</td>
<td>Concrete slabs</td>
<td>Superintendent</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Cast-in-place concrete columns and walls</td>
<td>Superintendent</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Erecting precast slabs</td>
<td>Superintendent</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Erecting precast walls</td>
<td>Superintendent</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Forming walls with stone cladding</td>
<td>Superintendent</td>
<td>24</td>
</tr>
<tr>
<td>Finishing activities</td>
<td>Brick masonry</td>
<td>Superintendent</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Stone cladding</td>
<td>Superintendent stone contractor</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Exterior plastering</td>
<td>Superintendent</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Gypsum boards</td>
<td>Finishing foreman</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Floor tiling</td>
<td>Finishing foreman</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Roof insulation</td>
<td>Insulation contractor</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Roof sealing</td>
<td>Sealing contractor</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Glazing</td>
<td>Glazing contractor</td>
<td>11</td>
</tr>
<tr>
<td>Other activities*</td>
<td>Electrical installation*</td>
<td>Electrical engineer</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Plumbing*</td>
<td>Plumbing engineer</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>HVAC installation*</td>
<td>A.C. Engineer</td>
<td>46</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td>348</td>
</tr>
</tbody>
</table>

* Activities performed during both structure and finishing stages.

### Table 4
Eight examples of event likelihood, including the most frequent and infrequent loss-of-control events.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sub-activity</th>
<th>Stage</th>
<th>Event</th>
<th>Average likelihood (occurrences per worker per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place concrete walls with stone cladding</td>
<td>Pouring concrete using a crane bucket</td>
<td>Filling bucket</td>
<td>Concrete spatter</td>
<td>168.0</td>
</tr>
<tr>
<td>Exterior stucco</td>
<td>Preparing the wall area</td>
<td>Filling holes</td>
<td>Dropping an object</td>
<td>116.1</td>
</tr>
<tr>
<td>Casting lightweight concrete for drainage</td>
<td>Pouring the concrete</td>
<td>Dropping an object</td>
<td>91.3</td>
<td></td>
</tr>
<tr>
<td>Concrete columns and walls</td>
<td>Fix steel rebar cage</td>
<td>Final tying</td>
<td>Collision with steel bars</td>
<td>70.58</td>
</tr>
<tr>
<td>Drywall construction</td>
<td>Erecting the framing</td>
<td>Attaching studs to exterior masonry or concrete walls</td>
<td>Spatter of debris from drilling or nailing</td>
<td>56.4</td>
</tr>
<tr>
<td>Exterior stucco</td>
<td>Manually applying an insulating layer</td>
<td>Curing and cutting protrusions</td>
<td>Struck by a tool</td>
<td>1.25</td>
</tr>
<tr>
<td>Cast-in-place concrete columns and walls</td>
<td>Installing forms</td>
<td>Cleaning and greasing forms</td>
<td>Fall from a ladder</td>
<td>0.060</td>
</tr>
<tr>
<td>Concrete columns and walls</td>
<td>Casting concrete with a crane</td>
<td>Lifting a bucket full of concrete</td>
<td>Crane collapse</td>
<td>0.0001</td>
</tr>
</tbody>
</table>
events a day, assuming 220 working days per year). As can be seen, activities with high levels of loss-of-control event occurrence are those performed outside and at height, whilst activities performed indoors have relatively low levels of occurrence. The least frequent event type is ‘floor collapse’, which according to the interviewees is expected to occur once in ten years of continuous work. Although it is very rare, the expected outcome of this event is disastrous and therefore, it is quite a significant risk.

3.2.2. Intensifying factors

Implementation of the CJaSA assessment step included examination of factors affecting the expected likelihood of occurrence of loss-of-control events. The respondents in step 2 were asked to assess, based on their past experience, how the likelihood of loss-of-control events would be increased during each work stage of the entire activity, in the presence of each of the following intensifying factors: schedule delays; a work group’s first day on site; crowding of workers in the work area; and short notice before work begins. As previously mentioned, the intensifying factors should be defined by the user in relation to the nature and context of the work analyzed; these particular factors were chosen in this research due to their potential to reveal correlations between safety and future implementation of lean construction practices. For each work stage respondents evaluated whether each factor, if it appears, intensifies the likelihood of an event occurring, on a scale from 10 (most significant) to 0 (no influence at all).

The most significant intensifying factor was found to be the first day on site, which had almost twice the effect on event occurrence probability as did the least significant factor – short notice. The relative influence of the factors remains almost the same across all of the activities, as can be seen in Fig. 5. The most affected activities are ‘Wall formwork with cladding’, ‘Exterior stone cladding’, and ‘Pre-cast wall erection’, although the difference between all the activities was small. The highest effect of all factors together on a single work stage (out of more than 300 work stages) was measured for ‘Releasing a pre-stressed beam’ (used for connecting piles) during ‘Piling’ activity. Some work stages are unaffected by any of the factors: examples are curing of stucco layers and tying reinforcement meshes for concrete slabs. The same result was found for similar work stages belonging to other activities. This reflects high reliability in spite of the small sample for each activity, since different respondents answered for different activities.

4. Conclusions

The CHASTE approach represents a progressive way to evaluate risks in construction. It confronts the difficulties and unique hazards of the construction industry by considering likelihood of loss-of-control events and exposure of potential victims to their consequences separately. The CJSA method provides a mechanism for collecting the extensive knowledge of the likelihood of loss-of-control events in construction that is needed for implementation of the CHASTE approach. The CJSA method is loosely based on the standard JSA approach to safety planning in manufacturing; it covers the first two stages of traditional JSA (identification and assessment), but does not extend to the ‘action’ stage, taken in order to reduce or eliminate the risk level, as defined by Chao and Henshaw (2002).
The CJSA method described was implemented for the construction activities and methods typical of the Israeli building construction industry, and a comprehensive analysis was conducted of its results. A number of lessons were learned from its implementation:

- The method is tractable, despite the large number of individual loss-of-control events that must be explored. In step 2, assessment of likelihood of loss-of-control events, each interviewee was able to respond to up to 85 events within 2 h.
- The need to obtain measures of likelihood of loss-of-control events, rather than of accident occurrence, meant that the interviewers had to explain the principle to each interviewee thoroughly in order to avoid responses based on misconceptions.

The major contribution of the CJSA method is that relative quantitative measures for each event are obtained. CJSA does not provide risk reduction measures in and of itself. Rather, it supports the compilation of essential data that is sufficiently rich to support the CHASTE approach.

Through the trial implementation, loss-of-control likelihood data were collected for 14 common construction activities from all phases of a typical multi-story building project. Not surprisingly, the activities with the highest likelihoods of loss-of-control events were those performed outdoors and at height.

References


