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Identification, analysis and dissemination of information on near misses: A case study in the construction industry

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ABSTRACT

Near misses are well-known for providing a major source of useful information for safety management. They are more frequent events than accidents and their causes may potentially result in an accident under slightly different circumstances. Despite the importance of this type of feedback, there is little knowledge on the characteristics of near misses, and on the use of this information in safety management. This article proposes guidelines for identifying, analyzing and disseminating information on near misses in construction sites. In particular, it is proposed that near misses be analyzed based on four categories: (a) whether or not it was possible to track down the event; (b) the nature of each event, in terms of its physical features (e.g. falling objects); (c) whether they provided positive or negative feedback for the safety management system; and (d) risk, based on the probability and severity associated with each event. The guidelines were devised and tested while a safety management system was being developed in a healthcare building project. The monitoring of near misses was part of a safety performance measurement system. Among the main results, a dramatic increase in both the number and quality of reports stands out after the workforce was systematically encouraged to report. While in the first 4 months of the study – when the workforce was not encouraged to report – there were just 12 reports, during the subsequent 4 months – when the workforce was so encouraged – there were 110 reports, all of them being analyzed based on the four analytical categories proposed.

1. Introduction

The use of data from near misses in safety management has been identified as an important practice in the prevention of accidents, especially in the areas of civil aviation, the generation of nuclear power, the chemical industry and, more recently, in railroad transport and medicine (Van Der Schaaf and Kanse, 2004). It is likely that their use has emerged in industries with high levels of safety, in which accidents are rare events and have very serious consequences (Reason, 1997). In this context, it is necessary to gather information about events that are indicative of the likelihood of accidents, as is the case with near misses (Brazier, 1994; Van Der Schaaf, 1995).

As near misses are much more frequent events that accidents, they may indicate, in a proactive way, critical areas for improvement in safety management (Hinze, 1997; Jones et al., 1999; Reason, 1997; Van Der Schaaf, 1995). In addition, using near misses helps to strengthen the safety culture (Cooper, 2000; Glendon and Stanton, 2000; Jones et al., 1999), especially when workers are motivated to participate in the process of identification and analysis of those events (Reason, 1997; Jones et al., 1999). Indeed, studies in the construction (Hinze, 2002) and chemical industries (Jones et al., 1999) have indicated that accident rates tend to diminish in keeping with the rate at which the number of near misses identified increases.

However, identifying near misses is not an easy task (Reason, 1997). Some factors that hinder their being reported, from the perspective of workers, have been identified by Van Der Schaaf and Kanse (2004): (a) fear of disciplinary action, as a result of a culture that seeks to blame staff for the lack of safety; (b) the acceptance of risks, since such events are regarded as being part of the job and cannot be prevented, as well as there being a macho culture in some industrial environments; (c) lack of feedback on how information reported has been used; and (d) the perception that data collection is difficult and time consuming.

Some studies have investigated how data from near misses should be used in safety management. However, each study tends to emphasize one of the following steps: identifying near misses, analyzing data and defining actions resulting from the investiga-

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tion of the events. For example, Brazier (1994), Reason (1997), Van Der Schaaf and Kanse (2004), Renshaw and Wiggins (2007) and Dekker (2007) focused on the stage of identifying these events. Bier and Mosleh (1990) addressed the analysis of near misses. The study by Van Der Schaaf (1995), undertaken in the context of the chemical industry, proposed a set of steps for the use of data from near misses: (a) detecting near misses, usually by means of voluntary reporting by employees; (b) selecting events useful for prevention, according to the quality and depth of information available; (c) analyzing the event selected using qualitative techniques from causal analysis; (d) classification according to the analysis of the causes; (e) statistical analysis of data from near misses in order to support management decision-making; and (f) assessing the effectiveness of actions implemented.

In the construction industry, the use of near misses in safety management appears to be a relatively recent practice. In a study on safety management best practices, Hinze (2002) identified their use in large construction companies in the United States, which had not been observed in a similar survey conducted previously by Liska et al. (1993). The study by Hinze (2002) also concluded that, on average, 22 near misses per project were documented and that 85.7% of construction sites recorded the identity of the workers who made reports. However, this study did not examine in depth how near misses were identified, analyzed and used to contribute to prevent accidents.

Studies on causal analysis of accidents are widespread in the literature, including in the construction industry (Hinze and Russell, 1995; Cameron et al., 2008). By contrast, despite the trends of causal similarity, there has been hardly any investigation of the nature of near misses, their different types and relative frequencies. This may reflect the difficulty of identifying them and the lack of legal requirements regarding their reporting and investigation. Moreover, there is no framework in the literature for identifying, analyzing and responding to these events.

Thus, this article proposes guidelines for identifying, analyzing and disseminating information on near misses, in order to support safety management in construction sites. In particular, analytical categories for such events are proposed, including whether or not it was possible to track down the events, their nature in terms of physical features, type of feedback to the safety management system and the risk associated with each event. These guidelines have arisen from a study involving the development and implementation of a safety management system in a construction project, which involved the construction of two multiple-floor healthcare buildings.

2. Concept and classifications of near misses

Near misses are usually referred to as precursors of accidents (Bier and Mosleh, 1990) or indicators of potential accidents when luck runs out (Brazier, 1994), thus suggesting that near misses should be interpreted as an imminent signal of accidents (Jones et al., 1999). However, these definitions are far from being precise, especially when one is seeking to differentiate a near miss from other situations, such as unsafe acts and unsafe conditions.

In this study, the authors have adopted the concept of near miss as an instantaneous event, which involved the sudden release of energy and had the potential to generate an accident. Its consequences do not result in personal injuries or material damage, but usually only in the loss of time. This concept also implies that a near miss has the potential to result in accidents with exclusively material damages.

This study also proposes that information on near misses be interpreted as being intermediary between information that is reactive and that which is proactive. On the one hand, although near misses have not led to injuries or material damage, which typically characterizes a piece of reactive information, there is a reactive feature in these events to the extent that a release of energy, typical of an accident, has already occurred. On the other hand, the proactive nature of a near miss is linked to the fact that the items of information generated allow actions to be performed, which will prevent injury or damage to property occurring in the future.

It is common to use the term near miss as a synonym of incident (Reason, 1997; Hinze, 1997). However, some authors consider that incidents include accidents, near misses, unsafe acts and conditions (Brazier, 1994; Jones et al., 1999, Van Der Schaaf and Kanse, 2004). In this article, 'incident' is an umbrella term adopted to refer to any situation in which there is a lack of safety.

It is also common for no distinction to be made between the terms near misses, unsafe acts and conditions. In this article, it is considered that the difference between these events is in the time of the action and in whether or not there has been a sudden release of energy. While in unsafe acts and conditions, the situation of risk arises from a continuous action or is latent in the environment (for example, an employee working high up who does not use a safety belt), in near misses there is an instantaneous action, which involves the sudden release of energy.

Jones et al. (1999) propose classifying near misses into two types, depending on the likely consequences of the event. The first, called extended near misses, are more serious and can give rise to an accident with consequences which extend in time and space, having an impact not only on individuals within the organization, but also on communities and the environment. In the European Union, chemical industries are required to report such events to governmental regulatory institutions, with to the aim of transferring the learning experience to other organizations.

In the second type, near misses are high risk situations that could result in individual accidents (Jones et al., 1999). According to Reason (1997), individual accidents are those to which an individual or a small group falls victim, thus showing that there may be serious consequences for those involved, but ones which have limited impact on the community or the environment. Reason (1997) suggests classifying near misses according to the type of feedback, whether positive or negative, to the safety management system. In the first case, preventive measures function as per what was planned or the worker manages to regain control. In the second case, the accident did not occur by chance, since the preventive measures did not work or did not exist.

3. Research methods

3.1. Sources of data

The data on monitoring near misses presented in this study were obtained as part of a broader study, which had the objective of enhancing a model for safety planning and control (SPC), previously developed by Saurin et al. (2004). This model for safety management has three hierarchical levels of decision-making (long, medium and short term), so that both hazards are identified and accident prevention methods defined in detailed over time, to the extent that uncertainty is gradually reduced. Every week, production managers, foremen, safety specialists and representatives of production teams hold meetings devoted to integrated planning between safety and production at the short and medium-term levels. Long-term planning is usually undertaken before the start of the project and updated throughout construction. As part of the SPC model, safety performance indicators are used to guide the actions of planning and control. In this context, near misses are a major source of information for monitoring safety performance.

The study was conducted in a construction project, which consisted of a 10 storey car park for a hospital and a 13 floor medical center building. This project was expected to last for 18 months, and was carried out by a consortium of two construction companies. One of them, deemed company A, has a partnership with UFRGS for conducting research in the field of safety management. This company showed great interest in improving its safety management system, especially because of the high demands of its clients. The research was conducted from the start of the production stage (earth-moving and foundations phases) to the stage of completing the structure of the buildings, and lasted for 8 months.

The construction site had a maximum of 300 workers, with 95% of them being subcontracted. Three subcontracting companies stood out due to their high number of employees, two of them being responsible for building the structure and the other for the installation of electric and water-sanitation services. Each of those three sub-contractors appointed a safety specialist full-time on the construction site as did company A. The sub-contractors' safety specialists were responsible for monitoring the work of their teams, and their work was supervised by company A's safety specialist.

3.2. Stages of data collection

The data on near misses were collected in two stages. In the first stage, which occurred over 4 months, there were no actions taken to encourage workers to report near misses systematically. During this stage, the researchers concentrated their efforts on implementing the three levels of planning that make up the SPC model, but did not emphasize the analysis of near misses. The second stage, held in the 4 months subsequent to the previous stage, was characterized by the formal involvement of the workforce in the process of identifying near misses. This involvement set out to increase the number of records and increase the detailed information on events, as compared with the first stage. In fact, any safety information system depends crucially on the willing participation of the workforce, the people in direct contact with the hazards (Reason, 1997). In the two stages of data collection, one of the researchers assumed the role of providing technical support to company A's safety specialist in the process of collecting and analyzing data.

3.3. Analytical categories for analyzing near misses

The analysis of near misses included classifying events into four categories: the traceability of events; the nature of the events; the type of feedback to the safety management system and the risk associated with the event. The assumption adopted was that these categories allow the understanding of the events to be deepened and support decision-making on preventive measures. However, analysis in accordance with these categories was performed only for the near misses collected in the second stage of the study, since the records of the events identified in the first stage was not sufficiently detailed. Except for the estimated risk associated with each event, the classification of near misses in the other analytical categories was undertaken after the completion of the field study by the researchers. This occurred because the SPC model did not provide for the analysis of near misses according to such categories.

As to the category of traceability of near misses, the need for it was perceived even during the first stage of data collection, since it was not feasible to investigate certain events due to the lack of information about them. Thus, those events which were not investigated for lack of information were considered non-traceable near misses, as opposed to events that were investigated, which were deemed traceable. It is important to stress that, even though their causes were not investigated, the non-traceable events did have enough information that allowed them to be analyzed in accordance with the other analytical categories. Although such analysis was not conducted in this study, the causes of non-traceability should be investigated and measures should be implemented to increase the number of traceable events, such as creating incentives or devising additional reporting procedures.

Near misses were also classified according to their nature, which involves the physical characteristics of the events. Initially, an attempt was made to classify near misses according to the categories of accidents prescribed in the Brazilian regulation NBR-14280 (ABNT, 2001). However, some adjustments were required, since those categories are not targeted for near misses. For example, new categories were created, such as people losing their balance and equipment being unbalanced. Nevertheless, several categories normally associated with accidents, such as falling objects and electric shocks, also proved to be suitable for analyzing the nature of near misses. This classification is useful mostly for building databases and identifying medium and long-term trends on the incidence of those events, similarly to what is usually done with accident data, such as physical features involved, hour of the day, day of the week and trades involved.

With regard to the category of the type of feedback to the safety management system, near misses were classified into events of positive feedback and negative feedback, based on the definitions by Reason (1997), given previously. The events with a positive feedback were further sub-divided between those in which control was regained due to the actions of the workers involved in the event and those in which the accident was avoided because there were physical barriers, the planning of which was determined by upper hierarchical levels.

In particular, there was interest in understanding the events with a positive feedback, since they may be interpreted as examples of resilience, which is being increasingly emphasized in the literature as a desirable property for the safety of complex systems (Hollnagel et al., 2008), as is the case for construction sites. According to Leveson et al. (2006), resilience is the ability to prevent or adapt to the circumstances in order to maintain control over a property of the system, in this case, safety or risk. Cook and Nemeth (2006) add that resilience is characteristic of systems that, after some disturbance, quickly return to their normal operating condition and with a minimum of decrease in performance. The near misses where workers regained control displayed stronger evidence of resilience in comparison with accidents that were avoided due to there being physical barriers. While in the first case the events demanded an immediate response to a threat that had not been foreseen, managers' decisions are temporally and spatially distant from the events, besides not involving taking immediate action and dealing with foreseeable threats, many of which are set out in the regulations covering them.

For practical purposes, the results of the analysis of the type of feedback might be used as follows: (a) if the feedback is positive, the reasons for success should be investigated and strategies for disseminating good practices should be devised and (b) if the feedback is negative, there were clear failures in safety management that demand immediate action.

The fourth category for analyzing near misses includes an assessment of risk associated with each event, in terms of the severity and the probability of occurrence. This assessment is needed to the extent that events of greatest risk justify deeper investigation and suggest priorities for implementing preventive and corrective actions. In order to reduce the subjectivity of the evaluation, criteria were established to classify near misses according to their degree of severity (level of impact if the accident had happened) and probability (estimate of the likelihood of an accident occurring if no preventive action additional to those already in place is taken), as shown in Fig. 1. Regarding severity, the adoption of a limit of 15 days away from work was adopted, because, in Brazil, after the 15th day of absence on sick leave, the National

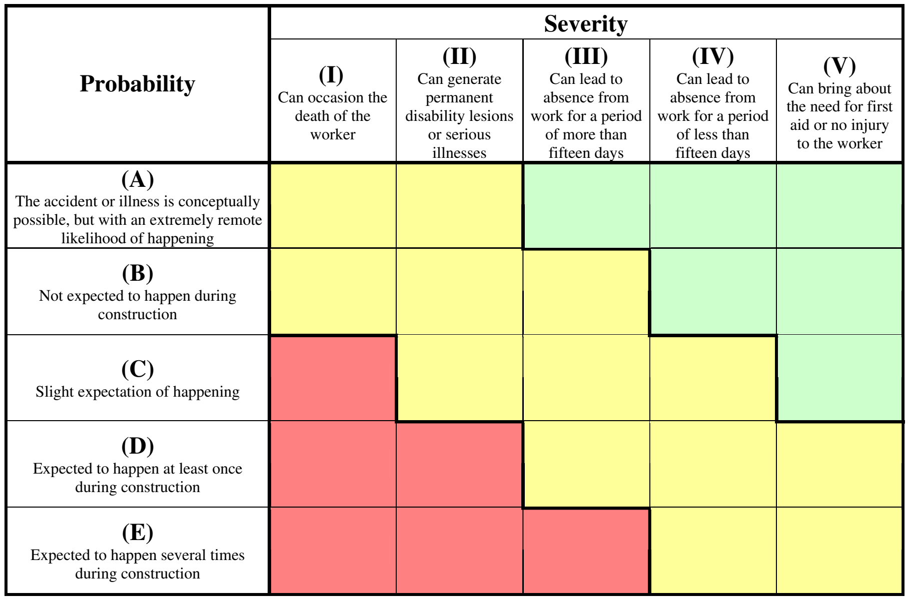

Fig. 1. Matrix to support risk assessment of near misses.

Institute for Social Security takes over bearing the costs of salaries and treatment of the victim of the accident.

The severity and the probability associated with each near miss will be the basis to classify the event in one out of three zones of risk (Fig. 1): red (events with the highest priority), yellow (events with intermediate priority) and green (events with the lowest priority)[2]. The classification in zones is necessary since the choice was made not to assign weights to rank each category of probability and severity. Therefore, the matrix in Fig. 1 provides a prioritization among zones rather than among cells within each zone. For example, while it is clear that the intersection I E is of higher priority than the intersection V A, the intersections I C and III E (both in the red zone) cannot be clearly distinguished in terms of priority. Of course, there are other similar ways to conduct risk assessment in safety management, with varying discretionary power, which could be fairly easily adapted for near misses and fit better to the context of other industries and countries (see, for example, Roughton and Crutchfield (2008)).

4. Results

The results are divided into two parts. Initially, a description is given of the procedures adopted for identification and recording of near misses, data analysis and dissemination of information, that were implemented on the construction site investigated. Next, the data collected from near misses are quantified and categorized.

4.1. Identification and recording of near misses

In the first stage of the study, near misses were identified through two main mechanisms:

(a) Interviews with safety specialists: 16 interviews were conducted, eight of them with company A's safety specialists and eight with the safety specialist from the sub-contractor responsible for erecting the structure of the buildings. These interviews were held weekly and, among other questions, the specialists were asked to report the near misses they had witnessed or those which had been reported by workers.

(b) Direct observations made by the research team: these were carried out by way of weekly visits to the construction site, and lasted for approximately an hour, during which, among other activities, the researcher talked informally to some workers by asking questions about the occurrence of near misses.

In the second stage of data collection, the mechanisms used in the earlier stage were replaced with three other mechanisms, which sought to increase the quality and quantity of reports. Some of the mechanisms used in this step were elements from the SPC model, which were gradually implemented along the project:

(a) Reporting of near misses by workers at daily meetings on safety: initially, training was given to all construction site workers, led by company A's safety specialist, during which the concept of near misses was explained (as set out in item two of this article) as was the importance of reporting them, and the fact that no disciplinary action whatsoever would be taken arising from such communication. However, since the concept used is fairly abstract, and this may be difficult for workers with low levels of formal education to interpret, they were also encouraged to report any lack of safety they would deem relevant. After this training, workers began to be asked questions daily about the occurrence of near misses on the previous day, though during the meetings it was considered irrelevant whether or not the fact of the report corresponded to a near miss. The questioning occurred during daily meetings on safety that lasted for approximately 20 min, being held before start of the working day. Each sub-contractor's safety specialist was responsible for meetings with their respective teams. Workers from sub-contractors who did not have safety specialists attended the meetings conducted by company A's safety specialist. Although reports were made during the meetings, it was noted that the workers preferred to report to the safety specialists or foremen privately during the working day. Given

[2] For interpretation of color in Fig. 1, the reader is referred to the web version of this article.

this situation, putting questions to them every day mainly contributed to raising their awareness as to the importance of identifying and reporting near misses.

(b) Reporting of near misses by employees at monthly meetings to assess safety conditions: some events were also reported during four rounds of monthly interviews with groups of up to eight workers. Such interviews were a channel for participation in the SPC model, called participatory cycle, in which workers contributed their perceptions on the site safety and proposed actions for improvement (Saurin et al., 2004). In spite of the small number of near misses identified in the participatory cycle, they provided additional evidence for events already identified through other means, enabling the collection of additional information that clarified some details. In contrast, the contribution of the participatory cycle was hampered by delayed access to information, as these interviews were carried out just once a month.

(c) Collection of the indicator percentage of safe work packages: this indicator is the primary metric of the SPC model (Saurin et al., 2004), and was collected during the last 2 months of the second stage of data collection. To collect this indicator, a member of the research team walked through the construction site every day and checked whether each process was being performed in accordance with the safety plans. In addition to this observation, the researcher talked to the workers, questioning the reasons for any non-conformity with safety plans and whether they had any near miss to report. As this data collection lasted approximately 1 h, representing a small sample of the day's work, the possibility of identifying near misses during the observations was small.

In this study, no mechanisms were used for reports written by workers, such as, for example, the use of record cards and their being deposited in urns. This option was made because construction workers seemed to be more inclined to participate through oral communication. Among the reasons for the use of informal means, rather than written (formal) ones, are the low educational level of construction workers in Brazil, and also the fact that oral communication is easier and requires less effort (Cameron et al., 2006). Moreover, the identity of those making the report was not documented, although the researchers and safety specialists could usually identify who reported due to the way data were obtained. On the one hand, the lack of this information made it impossible to investigate whether the reports came with a higher frequency from one particular group of workers. On the other hand, this option helped reducing the workers' fear of making reports. This strategy was adopted because the company did not have a reporting culture (Reason, 1997) and this was its first initiative of involving workers in near miss reporting.

The records of near misses identified by all sources of collection were organized on a weekly basis by the researchers and passed onto company A's safety specialist, who investigated the events and reported the results of the investigations to the sub-contractors' safety specialists.

4.2. Data analysis

Data analysis began with the organization of data, after excluding the events that were not considered near misses according to the concept adopted in this research. It must be emphasized that some events that were excluded were important for the safety management. However, for the purposes of this study, they were not analyzed because the objective was to investigate near misses only. During the organization of the data, attention needed to be paid that the same event was not registered more than once due to the different data collection mechanisms and to the possibility of different workers witnessing and reporting the same event. Despite the need for taking such care, the possibility of obtaining the data through different sources favored a better understanding of the events, since different sources of evidence often presented complementary information. In some cases, it was also necessary to seek further clarifications on the events from the workers who reported or witnessed them.

In this study, near misses were treated in a similar way to accidents, with investigation being made into their causes and the controls being reassessed, in addition to the analysis based on the four classification criteria described in Section 3.2. However, as these are about events which are more frequent than accidents, which increases the total time required to investigate them, the report produced for each event was as succinct and objective as possible. Company A's safety specialist completed the investigation spreadsheet presented in Fig. 2, which was used for events identified from any of the data collection strategies. In this spreadsheet, dates and times of events were entered on as were the employee or the team present at the location of the event, a description of the facts, the immediate causes identified and the corrective actions proposed.

The safety specialists generally attributed the causes of near misses to the actions and behavior of workers. This indicated that there was no emphasis on investigation into the root causes and that the paradigm of safety management in the company was still strongly linked to identifying the culprits who caused failures, without understanding the organizational context that contributed to human error taking place. Moreover, it is worth mentioning that in a number of cases the events were not complex enough to allow the root causes to be identified, such as the case of a worker who stumbled over his own legs, in an open area and with no elements in the environment that could have aggravated the event.

4.3. Dissemination of information regarding near misses

Passing on information about near misses was restricted to the construction site investigated and did not cover other sites the company had. The daily safety meetings were the main mechanism for transmitting information on the occurrence of near misses to the workers and, possibly, of the corrective actions planned after these near misses had been analyzed. However, since company A's safety officer received the records of near misses from the researchers only once a week, the deadline for giving a feedback to the workers on prevention solutions, most of the time, took more than a week.

However, what was regular, just after the identification of a near miss, was to disseminate information on it at the meeting on the following day in the register. Thus, the workers were only alerted as to the event, which characterizes initial feedback without corrective actions being specified. The actions in response to near misses were usually defined by company A's safety specialist or by him together with the production manager. Both participated, along with foremen and representatives of sub-contractors, in the weekly meetings of the integrated planning between safety and production, in which the information on near misses contributed to guiding planning decisions.

4.4. Analytical categories of near misses

4.4.1. Traceability of near misses

Among the 110 near misses identified in the second stage of the study, 96 were classified as traceable (87.3% of cases) and 14 as not traceable (12.7%). An example of a non-traceable event was the near miss reported by a group of workers who worked in the interior of a floor and saw a piece of wood falling on the periphery of the floor. However, they did not interrupt their work to analyze

Date and time	Team or employee	Description	Causes	Corrective actions
16th July 2007 2:20 p.m.	Carpentry (formwork removal)	During removal of formwork on the 5th floor, a panel fell down near a worker on the ground floor.	No signposting of risky areas on the ground floor.	Guidance related to the isolation of risky areas

Fig. 2. Spreadsheet for recording and initial investigation of near misses.

the incident nor did the workers involved in the task that used the piece of wood. Thus, though the record was made, it was not investigated.

One of the objectives of an information system on near misses should be to extend, to the maximum degree, the number of traceable events, which in turn depends on strategies suitable for identification and registration purposes. Although no figures have been found in the literature for comparison, the relatively high rate of traceable events indicates the effectiveness of strategies for collection during the second stage of the study, in terms of detailing the information obtained in a satisfactory way. However, it is suggested that targets should not be set for non-traceable and traceable events, since this can lead to a built-in tendency not to report events that may have been erroneously interpreted as not traceable, by those who witnessed them. This classification should be made later on when the reports are analyzed.

4.4.2. Nature of the near misses

Table 1 shows the classification of the 110 near misses identified in the second stage of data collection, according to their nature. Half of the events were related to falling materials, tools and equipment, whether at different levels (31) or the same level (24). This information could support decision-making regarding improvements in the processes that originated most of the falling objects, such as formwork. In fact, the formwork technology used in this project was craft-based, and generating a fairly large amount of residues. Besides, some of its components were very heavy to handle.

The predominance of these two classes can be explained partly by the construction stage at which these data were collected (erecting the structure of the building) and by the visibility of these events, since several people at the same time were in a position to observe them. In fact, the nature of near misses may vary with the construction stages and, consequently, with the number of jobs being performed simultaneously. For example, during the earthmoving and foundations stage, the main near misses may be related to stumbling and the imminence of being crushed by heavy machinery. During the erection of the structure, falling materials and equipment on the same level or at different levels may be predominant, as identified in this study.

In particular, the analysis for this category indicates that the events recorded adhere to an essential characteristic of near misses, in accordance with the definition provided in Section 2, which refers to the sudden release of energy without these having caused injuries or material damage. Among the eleven categories shown in Table 1, in nine of them energy was originally released by the movement of equipment, tools or materials, whereas in only two (a worker losing his balance and to the impact of the worker against stationary objects, which corresponded to 18% of all events), did the workers themselves initially release energy which could have resulted in their becoming victims of an accident. These results indicate the importance of mechanisms that warn when sudden releases of energy occur (for example, shouting out loud to warn of the imminence of an accident, in the case of falling materials), since the sources of hazard seem to be directed at workers rather than vice versa. One of the categories presented in Table 1 (electric shock) also provides the insight that a difference between a near miss and an accident might be the amount of energy that was released. Indeed, regardless of the electric shock, workers were not harmed primarily because the discharge was too small.

4.4.3. Type of feedback to the safety management system

Among the 110 near misses, 16.3% of them were classified as positive feedback and the remainder (83.7%) as negative feedback. An example of a near miss with a negative feedback occurred during the assembly of a metal shoring tower (Fig. 3), which saw the fall of the plank that supported the worker because there were no lower planks that would prevent its slipping. By contrast, a near miss with positive feedback occurred during the dismantling of one of those towers, which was positioned near the edge of a floor. Because the shoring tower was wedged between two ceilings, it was dismantled by knocking it down which was controlled by the workers using ropes. While one of the towers was being

Table 1
Classification of near misses according to their nature.

Nature of the near misses	Number of events	Examples
Falling materials, tools and equipment over different levels	31	A falling piece of scaffolding which was being assembled on the 4th floor, to the basement
Falling materials, tools and equipment at the same level	24	Live cables, which were caught in a beam, fell on a circular saw and its operator
Impact suffered by worker	10	Fall of a temporary panel on a worker when it was being removed
Worker losing his balance	10	A worker got his foot stuck in the frame used in the structure of the flooring of the basement
Impact of the worker against a fixed object	10	A steel bar perforated the boot of a worker and grazed his ankle
Imminence of impact involving machines and equipment lifting and moving loads	9	Due to the positioning of a reflector above the scaffolding for pouring concrete into the pillar, the vision of a worker was impaired and the bucket of a crane almost hit him
Impact of machines and equipment lifting and moving loads	6	While lowering a pre-molded piece, the crane had an electrical fault which caused the piece to clatter all the way down the scaffolding
Throwing materials and tools	4	A claw hammer was thrown from one floor to another and almost hit a worker
Imminence of scaffolding and ladders falling with workers on them	3	The employee fixed his belt to a scaffolding tower which was not duly fixed and the tower almost fell with the worker on it
Electric shock	2	A worker suffered a small electric shock from a central box for distributing electricity
Attrition and abrasion	1	While pouring in concrete when it was raining, the worker's leg was marked because of attrition by his rubber boot

Fig. 3. Activity of mounting and dismantling shoring towers which generated near misses with both positive and negative feedback.

knocked down, there was a loss of control and the worker was pushed against a peripheral guardrail, which avoided his falling to the lower floor.

The high percentage of near misses with negative feedback indicated the great potential for learning through the correction of flaws, since barriers did not exist or they were not effective. By contrast, the near misses which displayed positive feedback showed the effectiveness of some physical barriers, which worked when required.

Five near misses with positive feedback were identified, among a total of eighteen events of this type, in which workers regained control. Such events are examples of resilience mainly at an individual level, although the organizational context might have favored the successful behaviors. In three of those events, the action was taken by the employee directly involved in the near miss and in the other two cases by colleagues who were nearby. One example of the first type was the case of a worker who, during the removal of temporary frames, managed to avoid the collapse of a metal shoring beam on the lower floor, by holding onto the same. An example of the second type occurred to a worker who was almost suspended by the crane during the transport of a pallet of ceramic blocks. The fork of the crane caught in the belt of the worker, but he was quickly released by another worker who was nearby and noticed what had happened.

Three positive feedback near misses with action in which the workers regained control involved the violation of good safety rules, even though the violations were also present in many events with negative feedback. Although these cases are ambiguous, since they are indicative of both success and failure in safety management, they were classified as a positive feedback to emphasize the adaptability of the people involved, as they responded effectively to the consequences of management failures far from the scene of the event. Two examples of such cases are described below, the first involving the resumption of control by the worker himself and the second by the team.

In the first example, the worker was operating a drill and was not using safety glasses, which is a violation of a good safety rule. This worker suffered the impact of a jet of powder on his face, took fright and almost lost control of the drill. In the second example, a scaffolding tower almost collapsed with the worker who was working on it. The safety belt of the worker was fixed to the structure of the tower, which, in turn, was not tied to any other structure. The collapse of the tower was avoided because the workers, who were close to the spot, managed to hold onto and move the tower to its original position. In this instance, there was a violation of a rule which stipulated that towers be fixed to a structure independent of them.

Specifically in buildings with more than four floors, the fall of materials and equipment, which occur frequently on the periphery of floors, can be considered near misses of positive feedback if they are retained by protection trays. These trays are required by Brazilian safety regulations for buildings with four or more floors. Thus, if the number of pieces retained by the trays were checked at the end of the month, the percentage of near misses with positive feedback could be greater than that obtained in this study. In future studies, analyses of this type could be conducted, thus providing more reliable figures on the distribution of near misses with positive or negative feedback.

One also needs to consider the degree of difficulty relating to identifying events with positive or negative feedback. It is likely that the near misses with negative feedback are easier to identify than the events with positive feedback, since, in the first case, the release of energy was completely effected, therefore causing greater impact and capturing the attention of anyone witnessing the event. In the second case, the energy was initially released, but soon thereafter, was blocked by human action or by physical barriers designed for this purpose. Thus, especially during the investigation of the events with a positive feedback, but also in cases of negative feedback, investigators should be aware of and try to minimize the outcome bias, which is perceived as a tendency not to seek opportunities for learning when there were no undesirable results (Dekker, 2007). For example, in the case of the workers who noted the wobbling of the scaffolding tower and held onto it, as well as in the case of the worker who saw the fork in the crane hooked onto the belt of a colleague, questions such as the following could have been investigated: was there a shout for help? Why did other people nearby not help? Had they already witnessed similar situation? Were there doubts about how to proceed in order to regain control?

4.4.4. Risk associated with near misses

The risk assessment associated with near misses was based on the criteria established in Fig. 1. From the 110 near misses recorded, those classified as of greatest risk (the red zone) accounted for 13.7%. Most cases (75.4%) fitted into the yellow zone, while the near misses of the green zone accounted for 10.9% of cases. This assessment indicates that, on the site investigated, some priority events were clearly identified (in the red zone), both for investigation purposes and for purposes of implementing responses to the hazards. An example of this type of event was the fall of one meter long pieces of steel from the crane on which they were being carried. It is likely that the perception of the high risk of the event and its having been seen by several people, contributed to this being reported. The risk assessment indicated the importance of details of such events being made known (e.g. number of people exposed, nearby hazards), which in turn requires a sufficiently detailed report.

5. Guidelines for identifying, analyzing and disseminating information on near misses in construction sites

Initially, it is important to point out that an information system on near misses should be integrated into a more comprehensive safety information system. Such a system should incorporate other information on safety performance, such as reports of accidents, unsafe acts and conditions, as well as information related to the critical analysis of normal work in the case of organizations that are at more advanced stages in terms of safety management. This means that there should be an integrated safety information system and that workers should be encouraged to report everything they think is relevant for safety management. The task of classifying the data should be assigned to safety specialists or other safety professionals, who could adopt particular strategies for dealing with each type of information (e.g. near misses could be analyzed based on the analytical categories proposed in this study). Nevertheless, this study proposes guidelines for the identification and registration of near misses (input), analysis (processing) and dissemination of information (output). Neither how to integrate such an information system with other safety related information systems nor the extent to which these recommendations are applicable to other safety information systems were investigated.

Regarding the objective of a near miss information system, it should be explicitly stated (Pasquini et al., 2008) and its main interfaces with other elements of a safety management system defined. For example, in the case of the construction site of the case study, information about near misses had the objective of complementing safety performance measurement.

Regarding the identification and recording of near misses, the following recommendations are made:

(a) Having at least one safety specialist on the construction site or another skilled professional in charge of training the workers in the procedures for identifying and reporting, and able to organize the data collected. Considering a broader perspective, such training should also aim at raising the workers' awareness to risk.
(b) Adopting strategies for periodic questioning of the workers about the occurrence of near misses, such as daily meetings on safety and the participatory cycle used in this study.
(c) Encouraging the development of a safety culture in which the emphasis should not be the search for culprits who caused the lack of safety, but rather the investigation of the systemic causes that led to human error. Although the development of such a culture is difficult, since it implies establishing what are acceptable and unacceptable behaviors, its existence tends to reduce workers' fear of reporting unsafe situations and this information being later used as a basis for disciplinary sanctions and legal actions (Dekker, 2007; Reason, 1997).
(d) Defining multiple sources of data collection in order to motivate the participation of a larger contingent of workers and to have access to more qualified information.

The stage of analyzing near misses starts by classifying their traceability. The investigation of the traceable events should be supported by the classification in accordance with the other analytical categories proposed in this study (nature, risk and type of feedback to the management system). The investigation should not emphasize the search for culprits, but rather the root causes of events. The investigations, if possible, should be carried out by a team comprising representatives of the workers who have seen or reported the near miss, especially in the case of events considered as priorities according to the assessment of risks. The following step is to define measures for improving safety, supported by the analysis based on the proposed analytical categories.

With regard to the stage of disseminating information about near misses, the following guidelines are put forward: (a) designating those responsible for passing on information to the workers and to the management team on the construction site, aiming at greater speed in the process of disclosure; (b) immediately communicating the actions in response to events to employees, even if these actions are provisional, while a more thorough investigation is still ongoing; and (c) information on near misses prioritized in risk assessment must be disclosed to other company projects, this task being made easier to the extent that the records and the analyses of data may have been computerized.

6. Conclusions

This article proposes that the use of near misses in safety management in construction sites be supported by an information system comprising three components: identifying and recording events (input), analyzing these (processing) and passing on information (output). Unlike previous studies, in this article all three components are considered together and recommendations are put forward for making each of them operational. Moreover, the practical implementation of the proposed system on a construction site generated some data on near misses in construction, which are scarce in the literature.

Regarding the identification and registration of near misses, the use of multiple sources of evidence is proposed, with variations in their formats and frequencies for data collection. This strategy creates the possibility of collecting complementary data. At the construction site investigated, two mechanisms for identifying and recording were used with greater emphasis: (a) daily meetings with the workers to ask them questions on the occurrence of near misses in the previous day; and (b) monthly interviews with groups of workers. However, the reports were, in most cases, made in private to foremen and the safety specialists, rather than directly during the daily meetings. The monthly interviews were, above all, channels to understand the events better, although having the limitation of delayed access to information.

The formal involvement of workers in the process of identification of near misses contributed to increasing the number of near misses recorded. In the first stage of the study, in which there was no such involvement, only 12 events were recorded with eight of them reported by workers (66.7% of events). In the second stage, which lasted for a period similar to the previous one, 110 near misses were recorded, 103 of them identified by the workers themselves (93.6% of events). When one considers the two stages of the study, 91% of reports came from the workers.

In the step for analyzing the data, it is proposed that each event be analyzed in accordance with four categories: (a) traceability, (b) nature, (c) type of feedback to the safety management system, and (d) risk. As to traceability, 14 events, from a total of 110 events reported, were deemed not traceable, because of the lack of adequate information which would permit further investigation. From the total of 110 events, the nature of 50% of them involved falling materials, equipment and tools, both at the same level and at different levels. Taking into consideration the type of feedback to the management system, only 18 of the 110 events, provided a positive feedback, thus reinforcing good practices or revealing the adaptive capacity of the individual or the team involved in the task. As for risk assessment, 15 events, out of the 110, were classified as high risk due to their severity and probability, and thus required both further investigation and more speed in implementing responses.

Regarding the dissemination of information, it must include all stakeholders such as workers, production managers, sub-contractors, including people that work in other projects of the company. The daily safety meetings are an alternative for passing on information to the workers, whereas the meetings of integrated planning between safety and production provide an alternative to spread information among the managers. Both for managers and for workers, transmitting information must include the reporting of actions in response to events.

As a result of the limitations of this study, at least three opportunities for future studies can be identified: (a) integrating information about near misses with a more comprehensive safety information system which also includes unsafe acts, unsafe conditions, accidents and adaptations during normal work; (b) expanding the database on near misses, using and applying the proposed guidelines in contexts other than the construction site investigated, both in terms of construction technologies as well as in terms of features of the safety management system; and (c) from such databases, to investigate the effectiveness and efficiency of different sources of identification and recording, according to criteria such as the number of reports, detailing the information and resources spent on implementing and maintaining each source.

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