Safety in the construction industry: accidents and precursors

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Abstract
Construction sites represent complex environments with particular characteristics and high baseline levels of risk in which accidents are a main point of analysis in much of the studies in the literature. Despite the inertia behind this accident-based focus, though, there is criticism that such a reactive approach often involves unreliable information about the special characteristics of the construction site and that the use of lagging indicators is not appropriate. Current trends have taken proactive approaches and made use of analyses based on precursors or leading indicators, which aim to foresee safety issues before they turn into actual incidents. But these two focuses are not independent, and new proactive measures must be developed and rigorous empirical validation. The objective of the current work is to present a critical review that considers these two approaches based on a meta-classification of studies on health and safety on construction sites.

Keywords: Occupational safety, construction, accidents, lagging indicators, leading indicators.

Introduction

The construction industry behaves uniquely and possesses distinct characteristics (Lucas 2010), which can be seen in the temporary nature and specificity of the work sites. For each site, there are companies, workers, and technicians, among others, that come together in one specific place at one specific time to create something new and unique while various processes—each with its own risks—take place and affect one another. Each site has its own identity, organizational structure, and human and material resources that extend beyond the individual identities of the companies involved. Processes, machinery, resources, and workmanship can be vastly different depending on the site. This high level of diversity leads to risks and safety measures that, again, are specific to each site, and also likely leads to problems when it comes to improving accident rates, which in the construction industry, are one of the highest and most prevalent in the world (Jannadi and Bu-Khamsin, 2002; Martínez Aires, Rubio Gámez, & Gibb, 2010; Swuste, Frijters, & Guldenmund, 2012).

So, construction sites are affected by a multitude of factors: the surroundings, the environment, structural considerations, and cultural factors, among others. And, in order to ensure safety and make the industry more efficient in this regard, an analysis that considers construction and these factors from a theoretical framework that allows for the creation of proactive health and safety interventions is a must. The present article aims to create a better understanding of the current state of health and safety in the construction industry by discussing the main approaches in the literature for addressing the topic.

Proposal for a meta-classification of studies on safety in construction

Establishing a taxonomy for studies on safety in construction is a complex task given the breadth of the field, the variability present in approaches that are used currently, and the vast number of variables involved. Of note, among the literature that attempts to make such classifications, are the following: an analysis of accidents or incidents; safety processes and management, including assessment and scheduling; and finally, the impact of the individual and the group, including a climate of safety, perceptions of safety, and behavior (Zhou, Goh, & Li, 2015a). There are other studies that include other elements—e.g., regulations, education, or design (Sánchez, Peláez, & Alís, 2017; Swuste et al., 2012)—but they are much fewer in number. The diversity of analyses and focuses can also be seen in metaphors, like those used by Visser (1998) or Hoewijk (1988), who pose two models for addressing accident prevention: one that focuses on the setting where the accident took place, and one involving an organization triangle made up of the structure, culture, and processes that affect workers' behavior. Though their work is undoubtedly of a high caliber, their classification structures, as we understand them, are rather complex, and a simpler and more understandable meta-classification is needed.

With this as the objective, the present study aims to distinguish between reactive and proactive focuses, the former being based on lagging indicators (Hinze, Thurman, & Wehle, 2013) which center on accidents that have occurred, and the latter being based on leading indicators (Gambatese, Behm, & Rajendran, 2008) which focus on precursor variables not related to actual accidents but rather the risk or probability that one will occur. Swuste et al. (2012) suggested something similar: an investigation focused first on accidents and secondly on prevention, i.e., a more reactive approach and a more proactive one.

Focusing on accidents is a strategy that has been widely used, despite its reactive nature (Liao & Perng, 2008), as the accident has already been investigated in order to determine responsibility, rather than for scientific reasons. Accidents are complex phenomena, as a series of causes in one situation could lead to an accident, while in another situation it might not, depending on the interrelation between the circumstances. While information on accidents can be useful for defining accidents of a particular kind, it is also true that no two accidents are the same. Along this line, the literature provides evidence for, on the one hand, the shortcomings of research based solely on accidents with ex-post-facto designs and lagging indicators with a limited capacity for generalizing results, and on the other hand, the lack of procedures for estimating levels of risk and information specific to where accidents took place, due mainly to a lack of empirical studies utilizing field data (Zhou et al., 2015a).

Despite the fact that reactive approaches are commonplace in construction safety, the newest approaches aim to move the focus of the analysis from the accident to its precursors. These studies use and aim to classify leading indicators (Grabowski et al., 2007; Sinelnikov, Inouye, & Kerper, 2015) that represent an early warning or a sign of a potential fault, thus allowing for the issue to be corrected before an accident takes place. They come from information provided by companies as they carry out their activities, promoting and leading to increased levels of safety without having to wait for an accident to occur (Reiman & Pietikäinen, 2012).

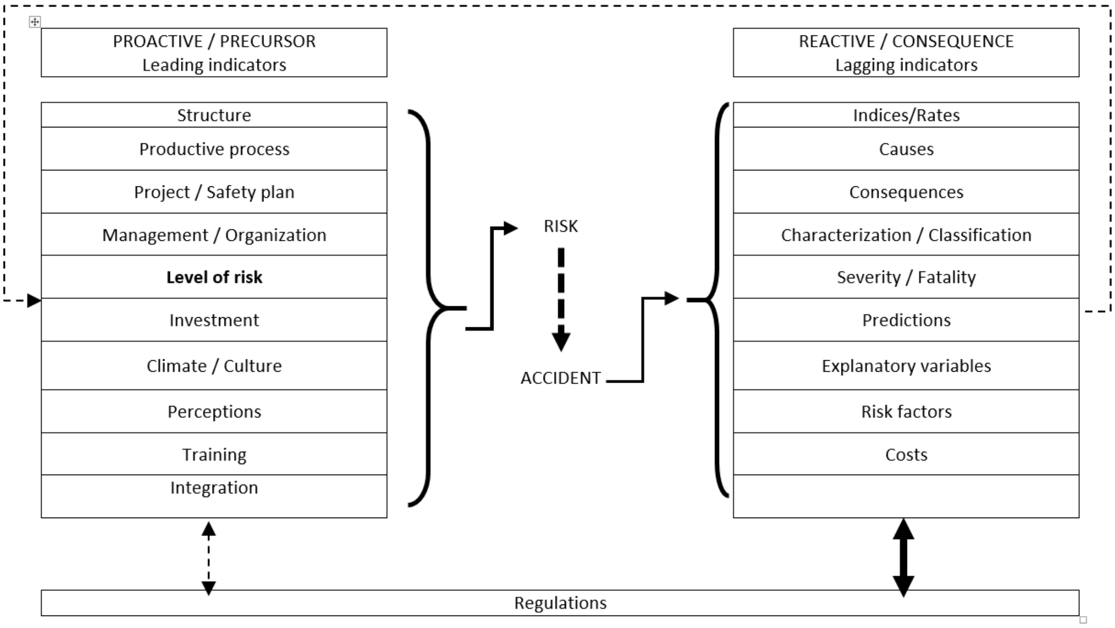
Figure 1 shows a concept map with the patterns that promote the use of the leading indicators, alongside those showing the more classic, accident-based indicators. The common ground between the leading indicators is the prevention and circumvention of accidents and the intent to avoid incidents by measuring or studying different elements that contribute to risk and ultimately the probability of an accident taking place. The common ground between the lagging indicators is that they use the accident itself to draw conclusions and make explanations, in addition to creating rates, trends, etc.

Obviously, these are not unrelated sets of indicators, as information from the study of accidents occasionally serves to determine precursors. The arrows in Figure 1 symbolize the interaction that each element has with each of the sets. At the base of the figure, safety regulations are included as an element that applies to both sets, but the relationship is stronger with the set of reactive elements and weaker with the proactive elements. Hereafter, we discuss the main elements that make up the reactive focus (based on lagging indicators), as well as the proactive focus (based on leading indicators), and how they relate to the minimization of risks and the prevention of accidents.

Studies based on lagging indicators

Focusing on accidents allows for relevant information to be obtained, but it also involves a lack of reliability when it comes to describing the setting and identifying events that took place. Cause-effect relationships should be identified in order to be able to come up with specific measures that can be taken. In the literature, reactive studies based on statistical extrapolation of accidents are highly criticized as they include little information on how they were created and on their content (Swuste et al., 2012). This study ends up highlighting and criticizing the strong disconnection between the professional and scientific fields when it comes to creating occupational safety studies; this is probably due to the need to assign direct or subsidiary accountability for the accident. The main lagging indicators that make up the reactive, accident-based focus, and which will be discussed in greater depth hereafter, are accident rates and indices, accident characterization, the severity and the consequences of the accidents, and costs.

Figure 1. Analysis of studies based on precursors and accidents (Source: own creation).



Accident rates and indices

The use of accident rates and indices is one, and perhaps the most, important indicator used by administrations. It is complicated to make comparisons between indices given the specific data analyses and the recording systems used. In general, there are also large differences in fatality rates in the construction industry across geographic areas (Nishikitani & Yano 2008). In Europe, the industry has the highest accident rate among all sectors of the economy. In Spain, figures show that the accident rate is twice that of any other sector of the economy (de la Orden Rivera & Zimmermann Verdejo 2010), thus it is the highest of any sector (Hinze et al., 2013; Martínez Aires et al., 2010) and is followed by the agriculture (Visser 1998; Zhou, Goh, & Li, 2015b) and industrial sectors (Martínez Aires et al., 2010; Sinelnikov et al., 2015; Zhou et al., 2015b). In construction industry falling from a height is one of the main causes of serious accidents and fatalities (Adam, Pallarés, & Calderón, 2009) and because of that, one of the first motivation for accident investigation.

So, analyzing causes has become an objective for explaining the accident and preventing future incidents, but this is always as a function of accident rates (Gambatese et al., 2008). Examples of this include studies that analyze the relationships between accidents and the business cycle, differences between countries, effects stemming from the creation and application of regulations (Saloniemi & Oksanen, 1998), or those that consider auxiliary resources, such as for example scaffolding in carpentry, as the fundamental cause of accidents (Cameron, Hare, & Davies, 2008). The problem with using accident rates resides in the pattern of inconsistencies that arises from real-life, not only in construction but also in all industries, where there is not a contingent relationship between high-risk situations and accident, in other words, risk might be very high even when the accident does not happen. In this way, chronically risky situations are masked by the nature of accidents themselves. One does not occur, but paradoxically, it could at any moment. This is the main shortcoming of this type of focus and the reason that it has limited preventive value.

Characterization, severity, and consequences of accidents

Another approach to reactive research with lagging indicators focuses on the consequences of accidents, incorporating their severity (whether fatal or not), and establishing distinct causal patterns (Lortie & Rizzo, 1998). However, putting the focus on the severity of the accident, especially fatal accidents, often means confronting analytical difficulties due to pressure from the various agents involved and corresponding penal processes. Thus, tools for studying non-serious accidents and even incidents have been suggested (Jørgensen, 2011), along with models that improve the understanding of their occurrence and avoid more serious accidents. However, in *a priori* high-risk situations, an accident does not necessarily lead to material damage, while other low- or moderate-risk situations could have fatal consequences. Once again, the nature of accidents makes predicting the severity of the consequences extremely difficult.

Immediate factors of the causes of accidents have also been studied—for example, the circumstances behind falls from a height when auxiliary equipment is used (e.g., ladders, scaffolding, and platforms as the cause of serious or fatal accidents). This approach involves identifying the dependent relationships between variables that caused the accident and defining a causal model that provides information that can lead to prevention (Camino López et al., 2011). The literature is also critical of the use of accident documentation systems that focus more on consequences than circumstances (Lortie & Rizzo, 1998). An important conclusion is that the difficulty of grouping and classifying accidents and the limitations of the automatic classification systems can bias data. Although data can be found regarding incidents, they are often ignored in studies of accidents.

In general, whichever the industry is, research into accidents aims to create lists of the most common events in order to prioritize the actions that should be taken. This is often studied using indirect means, without directly seeing or assessing the work site. Research is carried out on the events that took place and is based on accident reports or statistics and participant questionnaires, but the specific characteristics of each accident, and the channel of causation that could have been in place, make it difficult to find well-defined patterns. This is one of the fundamental reasons for which more recent studies have suggested radically changing the focus from the accident to the risk present with an interest into the identifying or listing the common factors affecting the risk of future accidents.

Costs from a reactive point of view

Under reactive approaches, the cost of safety, both with regard to prevention and in mitigating the consequences of an accident, is a topic that is addressed in the literature (Forteza, Carretero-Gómez, & Sesé, 2017b). Costs, in this sense, are related to the problem of contingency between risk and an actual accident, and the purpose of a safety system that aims to ensure that nothing undesirable happens. In general, this reflects the disconnection between unsafe practices and their financial consequences. Thus, many contractors only implement the most basic safety measures (Cheng, Lin, & Leu, 2010). Some researchers have developed systems for estimating health and safety costs and found that it represents about 5% of budgets (Cheng Lin et al., 2010; Ibarrondo-Dávila, López-Alonso, & Rubio-Gámez, 2015). Other authors have estimated that such costs account for 1.9% of the budget in residential building projects (Gurcanli, Bilir, & Sevim, 2015). Some studies go beyond, trying to relate accidents with the economic performance of companies, and they have found a relationships in the short and long terms (Argilés-Bosch et al., 2014; Forteza et al., 2017b). One of the fundamental problems related to costs from a reactive point of view is the perception of the business that, no matter what they do, they will end up paying for the costs of an accident if it takes place. In this way, they end up "rolling the dice" with the minimum investment required to avoid punishment, and only pay if an accident occurs. Rigorous studies are required that, on the one hand, assess the direct and indirect costs of accidents (Ibarrondo-Dávila et al., 2015), and on the other hand, put a number on the positive effect that investments in health and safety have.

Proactive studies based on leading indicators: focus before risk

Proactive studies use leading indicators, which are able to provide information on what may happen in the future. Such studies suppose a change from the reactive to the proactive, although they involve adopting preventive measures that may be suboptimal (Hollnagel, 2008). This perspective is based on the fact that safety problems cannot be solved solely by investigating accidents and relying on corresponding corrective actions (Hinze et al., 2013).

In turn, leading indicators can be passive or active. Of note among passive indicators are training, defining preventive criteria when selecting subcontractors, or requiring subcontractors to provide specifically adapted plans for the work to be carried out. Of note among active indicators are the level of participation of bosses or supervisors in meetings, previous planning meetings, the results of substance abuse tests, safety audits, involving developers in safety, and worker oversight. Ideally, leading indicators should include all of the agents involved on a construction site: workers, foremen, managers, clients, developers, architects, engineers, and subcontractors.

An example of using leading indicators is the safety inspection system based on incentives implemented by the construction safety group at Harvard University (Sparer & Dennerlein, 2013). It is carried out by having investigators enter data into an application that uses advanced software and predictors to detect situations in which an accident may potentially occur. Hereafter, we explain different approaches that make use of leading indicators, though, as can be seen, some come from studies based on accidents, but the evidence gathered therein provides information for leading indicators (Adam et al., 2009; Khanzode, Maiti, & Ray, 2012; Liao & Perng, 2008; Saloniemi & Oksanen, 1998).

The safety management process. Organizational structure

An organizational structure represents a complex factor that exists in different ways at different work sites, and monitoring and control systems depend on this structure. There are few empirical studies on the influence that internal structures have on prevention in construction projects (Zhou et al., 2015a), even though there is a consensus in the literature regarding the role that management plays in prevention. The complexity present in this element can have an influence on two levels: first, on the internal structure of the company, and secondly, on the site itself, where other factors, like subcontracting, for example, can lead to negative effects (Kartam, Flood, & Koushki, 2000; Manu et al., 2010, 2013). In this way, the organizational nature of the project (Swuste et al., 2012) affects the structure of the company, and vice versa. Few studies, however, have given any weight to these specific conditions and their impact on safety. Despite the fact that, in this regard, most studies make use of lagging indicators, there is a line of study that focuses on leading indicators related to management, though it is very recent (Cheng, Ryan, & Kelly, 2012; Forteza, Carretero-Gómez, & Sesé, 2017a; Manu et al., 2013; Törner & Pousette, 2009; Wu et al., 2015).

Size

Some studies have sought to associate the size of a company with accidents (Saloniemi & Oksanen, 1998), and the results have been contradictory (Camino López et al., 2008) as some have shown a direct relationship and others have shown an inverse relationship between the variables. These results are probably correct, as particular, complex relationships often arise and require a further analysis between the size of the company and the risk of accident. Other studies have considered factors related to the structure of the site; (Cheng Leu et al., 2010) and provided evidence of a strong correlation between accidents and private projects with relatively smaller budgets. The size of the company is related to its structure and internal management system. Studies focusing on small-scale building projects, such as, repairs, renovations, and expansions, have found that the main causes of accidents are the low levels of safety awareness and the concurrence of circumstances that facilitate accidents (Hon, Chan, & Wong 2010). While many studies use accidents to justify this relationship, others do so using field data (Fang et al., 2004; Forteza et al., 2017a; Manu et al., 2010). And, when using a proactive approach, it is necessary to provide evidence of the relationship that either the size of the company or the site's structure or management system has with the creation of risk, and therefore accidents.

Project

The integration of prevention from the first moments of managing a project is a key factor when it comes to managing risk (López-Arquillos & Rubio-Romero, 2015). The objective is to reduce the probability and severity of accidents via the application of preventive measures and the monitoring of consequences. In this area, studies have analyzed the mutual influence of business management and consequence monitoring by considering the influence that standard safety management practices have on the execution of the project (Cheng et al., 2012). Others have analyzed the relationship between the project and the occurrence of fatal accidents (Behm, 2005) and found that one key barrier to prevention during the design phase is the separation of the design process from that of contracting builders. Design is a key factor, but it is not the only one. Relationships between the developer, contractor, and architect determine each situation, which is then influenced by financial conditions. It is important to point out the limited possibilities that authorities have for regulating this area and the need to apply a holistic approach (Frijters & Swuste, 2008; Gambatese et al., 2008). Other studies (Hatipkarasulu, 2010) aim to categorize project typologies that are associated with fatal accidents. There has been evidence of a direct impact of the identification of these high-risk typologies on work sites which has been useful for specialized contractors. This identification has allowed for work and interventions to be more precise.

Finally, a significant part of studies provide tools for measuring risk during the project phase (Aminbakhsh, Gunduz, & Sonmez, 2013). Examples include the *analytic hierarchy process*, which is applied during the planning and budgeting phases of a project, or the *occupational risk model*, a system for quantifying risk in building projects which analyses construction jobs and assesses workplace risks based on their consequences (Sousa, Almeida, & Dias, 2014). A proactive point of view should consider the significance of studying risk factors in the design phase and it should do so in a way that considers all of the agents involved.

Management

The management system is one of the most important leading indicators given that throughout the construction process, the risk management system depends on it. Various studies have considered the safety factors that affect the success of management systems, including training, project meetings, accident investigation, supervision and control, emergency procedures, on-site meetings, etc. (Ismail, Doostdar, & Harun, 2012).

Other studies have suggested assessing companies and their attitudes toward and level of commitment to safety management. The main findings note that the presence of medium-high levels of commitment to safety management is not directly reflected in being proactive toward health and safety. Thus, work must be done to change the culture of safety in organizations and how they see safety management activities. Studies have pointed out the basic need to redesign systems, and base them on planning, detection, action, and feedback from workers to see how these activities interact (Mohamed, 1999). And throughout these processes, a specific commitment from upper management to the proper functioning of the management system is required. Some studies have found a relationship between safety management and a reduction in accident rates, increased competitiveness, and improved economic performance (Fernández-Muñiz, Montes-Peón, & Vázquez-Ordás, 2009). Specific safety management systems, such ISO 45000, must be adjusted to be compatible with, for example, quality and environmental policies (ISO standards 9001 and 14001) (Zeng, Tam, & Tam, 2008). It seems clear then, that with regard to management systems, organizational commitment and leadership are the most important factors for companies (Mahmoudi et al., 2014). Though these kinds of studies were first undertaken in the 90s, their findings are still pertinent and relevant today.

Costs from a proactive point of view

Health and safety costs have been studied from a proactive point of view, and it has been found that the number of accidents is inversely proportional to prevention costs, despite the fact that the number of accidents varies directly with the number of total workers, subcontractors, and the safety budget (López-Alonso et al., 2013). The proactive point of view suggests the need to create a budget specifically for health and safety, apart from the budgets related to any competitive bids, as this measure is very favorable to actually employing safety measures on site (Chan, Chan, and Choi 2010; Choi, Chan, & Chan, 2011). So, health and safety costs should not be conditioned by the general budget of the project, firstly for allowing to get safety measures independently from other financial aspects of the project, and secondly for showing an explicit safety commitment with a direct effect on risk management and the occurrence of accidents (Sousa et al., 2014).

On-site processes

One of the most recent leading indicators is the consideration of on-site processes that take place as the project is being carried out (Swuste et al., 2012), that which takes place as the consequence of the sequential organization and planning of each task during successive phases of the project. Some studies have considered the relationship between the project and the probability of an accident occurring considering so-called *construction project features* (CPFs): the nature of the project (a new project, repair, demolition, maintenance), the method of construction (determined by the developer, related to the level of manual work required), location-related restrictions (lack of space, coincidence of operators and machinery, vehicle maneuverability), length of the project (initial timeframe, overlapping with other activities, coincidence, pressure), the complexity of the design (aesthetics versus functionality as it relates to the ease of carrying out what is required), the contracting system (one contract for the project and all of the work, or multiple contracts), and the level of what is being built (presence of work from a height) (Choi et al., 2011). Generally speaking, the CPFs determine risk or contribute to increasing or creating risk, and the literature has demonstrated the influence that they have on accidents.

A notable example of process analysis can be seen in a study on formwork and falls from height that focuses on the phases of the process in which workers are more exposed to falls from a height, one of the greatest risks in the construction industry (Adam et al., 2009). Evidence from the study concludes that all of the systems present have weak points, and with regard to practical applications, tasks cannot be performed safely if proper equipment and processes are lacking. The safe performance of tasks depends on the prior definition of the processes involved as well as their analysis and preparation. Without this prior preparation, work must be improvised based solely on previous experience and criteria from intervening agents, and this can lead to a lack of safety. Some authors have pointed out this particular problem, but in general, the relatively few process analyses that there are tend to focus more on the project itself.

Culture, climate, groups, and individuals

Other leading indicators that have been considered are the climate and culture of safety. Those are two different, yet intimately related constructs, given that the culture of safety represents the stable development framework for the knowledge, beliefs, perceptions, and attitudes that exist in the context of the construction industry (Choudhry, Fang, & Mohamed, 2007; Guldenmund, 2007) and whose influence leads each company, even in large-scale projects, to come up with a certain climate of safety that can be defined by the set of perceptions and beliefs that workers share with regard to the company's safety policies. In this way, safety appears to be an organizational value that depends on the organizational decisions that are made (Guldenmund, 2007) and how related actions are perceived by workers. Safety standards are created from confidence, respect, cooperation, and contribution (Törner, 2011). The bases for creating an environment with an optimal culture of safety that promotes a favorable climate are complex interrelationships that must be addressed in an integrated way. The majority of studies that focus on culture and/or climate evaluate the impact that these constructs have on the safe behavior of individuals. They highlight the importance of supervision and relationships among peers, and note that workers' perceptions of the involvement and commitment of management to safety have an even greater positive impact than other factors, even experience or training in matters of safety.

The role of regulations in health and safety

Present in all construction-related approaches to health and safety are the structuring and stringency of regulations. One of the fundamental problems that regulations can lead to is the bureaucratization of accident prevention. With regard to regulations, expressions, such as "manage the risk not the paper" (HSE, 2009) offer evidence of the magnitude of the problem. It is absurd to discuss the need for regulations, but they require inspections in order to ensure results (Yassin & Martonik, 2004), and they should be highly intelligible and applicable.

For example, since the European directive on health and safety at temporary or mobile construction sites (92/57/EEC) was enacted, various authors have considered the impact of its application. In order for it to be effective, it has been pointed out that all related agents must be involved, the importance of an accident and risk prevention plan, on-site supervision with auditing systems to monitor day-to-day safety (a change of focus from bureaucratic to more practical), and the importance of the safety coordinator, both in the drafting and the execution phases; it has also made note of the difficulty for small- and medium-sized companies to comply with this directive (Baxendale & Jones, 2000). Furthermore, it seems to be key to focus on design in the drafting phase as a principle control tool (Esteban Gabriel, 2011). Some studies have assessed the repercussion of the implementation of the directive in terms of improving accident rates in each EU member state (Martínez Aires et al., 2010), and found high levels of variability: a reduction of more than 10% in 10 countries, a reduction of more than 10% in three other countries, and two countries who saw accident rates worsen. In general, however, the directive resulted in a reduction of the incident rate and represents a move in a positive direction. Nevertheless, local policies must be analyzed with respect to the implementation of the directive, as well as the technical requirements that represent barriers (protections and systems), in both successful and unsuccessful cases (Esteban-Gabriel, 2011).

Burdensome formal requirements and the complexity of the regulation are two ingredients that have contributed, in the case of Spain, to so-called "formal prevention compliance," which has led to regulatory changes, e.g., Law 54/2003 which altered the regulatory framework governing occupational risk prevention. Also present in this context, and on the same level as Royal Decree 1627/97 on construction (the implementation of the construction directive), is Spain's General Agreement for the Construction Industry, which in some cases (scaffolding, for example) has more stringent or specific provisions than the European directive or Royal Decree 1627/97. In addition to redrafting some of the articles of this royal decree on construction, the agreement also modifies part of Royal Decree 1215/97 on workforce, Royal Decree 2177/97 on workforces performing at a height, as well as other regulations.

The result of all of this is an amalgamation of laws and regulations that, in general, make it very difficult to specify exactly which characteristics a specific protection must possess. All of this affects the feasibility of the regulations, increases doubts, and makes effective implementation difficult (González García, 2010; Rozenfeld et al., 2010; Zou, Sunindijo, & Dainty, 2014). Both the disconnect between different laws and regulations and their level of complexity contribute to the bureaucratization of safety, and this undoubtedly promotes the use of reactive, or even passive, approaches to managing risk and accident prevention. For example, in de context of Spanish Health and Safety Inspectorate, there are special inspection campaigns directed to companies with high accident rates (Segarra Cañamares et al., 2017), especially in construction sector, one of the highest in rates. The administration uses often this lagging indicator as a criterion for intervention. Although limited, there are also examples of proactive campaigns such as finals' one with good results (Laitinen and Päivärinta, 2010).

Discussion and Conclusions

The analysis carried out outlines an extensive field of research involving many causal pathways, yet which seems to be disjointed. Research has generally taken advantage of the accident as the base of the study, even though this approach has shortcomings and often lacks direct information regarding the context and the setting in which the construction site took place. Other elements that are involved, including causality, management, regulations, climate, culture, and project, are considered individually. The complexity of the relationships between the various ways of studying, classifying, and combining factors, and the resulting difficulty in identifying risks and developing effective safety procedures is a major problem (Cheng Lin et al., 2010). Furthermore, there seems to be a certain disconnect between the academic and professional worlds when it comes to studying workplace safety, this is another major problem that requires more attention (Swuste, Gulijk, & Zwaard, 2010).

Reactive points of view and lagging indicators use the accident as the main source of information in trying to explain what happened and in predicting future behavior. However, many studies point out that statistical information stemming from accidents cannot be extrapolated to all contexts and environments, which are specific to each project. The concurrence of events that leads to risk in one circumstance will not give way to the same situations at all construction sites.

The current context is characterized by a debate on the adequacy of studies based on accidents, their limitations, and the need to develop a procedure to estimate magnitudes of risk (Swuste et al., 2012). A comprehensive focus that does away with the direct association between the setting of one accident and other settings with similar characteristics is needed, as this association can lead to the domino effect or the iceberg metaphor, both of which stem from the use of statistics from accident analyses without regard to the origin of the data or how they were handled (Swuste et al., 2010). But current research is beginning to change these trends and focus toward field research, using leading indicators, precursors, on-site process suitability, and the impact of existing structures on each particular project, in terms of an "impartial, proactive" focus (Khanzode et al., 2012). The integration of suggestions from the academic and professional worlds into mixed model approaches have enabled synergies between the two different spheres (Swuste et al., 2010).

Another significant aspect that requires rigorous empirical exploration is the effect that the structure of the site and the health and safety conditions have on one another. Each company has their own systems and methods that enable them to organize in their own way. And on each site there are, along with the leading company, one or more subcontractors, in addition to the developer, and all of them represent specific ingredients that together add unique characteristics to each worksite. Each agent has his/her role when it comes to participating in risk management. The contractor, from the internal systems and processes resulting from the organization of their company, must ensure that a common effort is made by all other contractors and subcontractors. The developer, being the agent that is moving the project forward and contracting different companies and technicians, comes up with budgets, deadlines, companies that will work together, building typologies, etc.

Changing the trend is possible. The culture of safety in construction can incorporate a proactive perspective as a value, using instruments that allow for levels of risk to be properly assessed through all of the processes of a project, starting with its design, and in order to include all of the factors involved (Aminbakhsh et al., 2013; Forteza, Sesé, & Carretero-Gómez, 2016; Fung, Lo, & Tung, 2012; Pellicer et al., 2014; Pinto, Nunes, & Ribeiro, 2011; Toellner, 2001; Wu et al., 2015). All agents involved in the process are important and create conditions on site that can lead to risk. Thus, it would be useful to make regulations more simple, understandable, and appropriate, in such a way that it would be feasible for companies in the construction industry to adopt a perspective based purely on prevention. In order to control risk, the origin of the risk must be controlled for and techniques based on leading indicators must be used to allow corrections to be taken before an accident occurs.

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