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Approach to identification and characterization of the new and emerging risks associated with Industrial Green Building

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Abstract

The subsector of industrial building has undergone changes in recent years. These have been: economic changes, as a result of the economic crisis experienced by the construction sector, structural changes because many companies specializing in industrial construction have disappeared, regulatory changes by the emergence of new requirements and functional changes because industrial establishments have been become an image of the brand or company.
These changes have led to the emergence of new risks to the safety and health of workers or have increased existing risks, assuming an increased exposure or severity of the effects on workers. These risks are referred to as new and emerging risks.
The aim of this communication is to carry out an approach to identification and characterization of new and emerging risks in the industrial green building subsector.

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Keywords: New and emerging risks; Construction; Industrial

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1. Introduction

Technological development and new production systems, the complexity of the organization of enterprises, new regulations, economic and social conditions, as well as the cost and time requirements of owners, tend to modify workplaces, where in addition to the traditional labor risks appear other risks, denominated new and emerging risks (NERs).

EU-OSHA [1] defines NER as any occupational risk that is both new and increasing. The risk means "new" if:

- C1. The risk was previously unknown and is caused by new processes, new technologies, new types of workplace, or social or organizational change; or,
- C2. A long-standing issue is newly considered as a new risk due to a change in social or public perceptions; or,
- C3. New scientific knowledge allows a long-standing issue to be identified as a risk.

The risk is "increasing" if the:

- C4. The number of hazards leading to the risk is growing; or
- C5. The likelihood of exposure to the hazard leading to the risk is increasing (exposure level and/or the number of people exposed); or
- C6. The effect of the hazard on workers' health is getting worse (seriousness of health effects and/or the number of people affected).

International and national labor safety agencies have determined the importance and necessity of research on NERs and their inclusion in new prevention models [2-4]. In Spain, one of the objectives of the Spanish Strategy on Occupational Safety and Health in the period 2007-2012 is research, development and innovation oriented towards the knowledge of new and emerging occupational risks, anticipation and prevention [5].

These governmental initiatives have led to the development of many research in the field of NER, such as the works of *Bartolomé et al*.[6] on emerging psychosocial risks at work and from *Brocal and Sebastian* [7, 8] who developed a methodology for the identification of NER in advanced industrial manufacturing processes.

In the construction sector, *Sanz Albert* [9] carried out a bibliographic study on emerging risks, identifying five scenarios of emerging risks:

- Green employment and waste management in construction.
- The aging of the active population in construction.
- Combination of psychosocial risk factors and physical risk factors in construction.
- New knowledge about the consequences of exposure to chemical agents in construction.
- Increased natural hazards in construction: solar radiation.

The subsector of industrial building has undergone changes in recent years. These have been: economic changes, as a result of the economic crisis experienced by the Spanish construction sector, structural changes because many companies specializing in industrial construction have disappeared, regulatory changes by the emergence of new requirements and functional changes because industrial establishments have been become an image of the brand of the company.

These changes have led to the emergence of new risks to the health and safety of workers or have increased existing risks, implying an increase in the exposure or severity of the effects on workers, i.e. have been developed new and emerging risks.

The aim of this communication is to carry out an approach to identification and characterization of new and emerging risks in the industrial green building subsector.

2. Methodology

The study methodology is structured in two steps. First a bibliographic analysis identifies the regulations that affect industrial building and the activities potentially generating NER. Secondly a risk characterization is produced according to the models collected in the works of *Brocal and Sebastián* [7-8].

2.1. NER Model

The model of NER developed by *Brocal and Sebastián* [7, 8] is based on some definitions. The first is the description of NER of the EU-OSHA [1]. Secondly, the definition two, has been developed from the EN 31010:2010 [10] and ISO 31000:2009 [11].

Definition 2: A risk (R) is a structure consisting of five components: the source of risk (SR), causes (C), events (E), consequences (CO) and the likelihood (L); this set may be expressed as (1):

$$R = (SR, C, E, CO, L) \quad (1)$$

This model (1), has been developed searching for its compatibility with NER definition as well as pursuing its use as the basis of a new NER model, as explained below. Thereby, R is the set of components that configure the risk (R = {SR, C, E, CO, L}), and C the set of conditions that define an NER (C = {C1, C2, C3, C4, C5, C6}), the Cartesian product of the sets R and C is equal to the set of all ordered pairs (r, c) that can be formed by linking the components of risk and conditions, it may be expressed as (2):

$$R \times C = \{(r, c): r \in R, c \in C\} \quad (2)$$

Thus, if Ɲ is the set of conditions that determine whether a risk is a new (Ɲ = {C1, C2, C3}) and ł is the set of conditions that determine whether a risk is increasing (ł = {C4, C5, C6}), the Cartesian product of the sets Ɲ and ł is equal to the set of all ordered pairs (n, i) that can be formed with the conditions that meet the definition of NER; it may be expressed as (3):

$$Ɲ \times ł = \{(n, i): n \in Ɲ, i \in ł\} \quad (3)$$

Therefore a particular occupational risk (R) belongs to the set of NER if and only if its components satisfy at least one ordered pair (n, i).

As shown in Table 1, of all ordered pairs algebraically possible according to (2) only those subsets compatible under the definition of NER are of interest. Thus, N (N c RxC) is the subset of all ordered pairs that satisfy the conditions that can define a new risk:

Ɲ = {(SR, C1), (SR, C2), (SR, C3), (C, C1), (C, C2), (C, C3), (E, C2), (E, C3), (CO, C2), (CO, C3)} and I (I c RxC) is the subset of all ordered pairs that satisfy the conditions which may define a risk that is increasing: ł = {(SR, C4), (CO, C6), (L, C5)} the NER model may be described with the definition 3.

Table 1. Compatible ordered pairs ("X") between risk components (1) and the conditions that define a NER.

Components of risk	Conditions that define a NER					
	NEW (Ɲ)			Increasing (Ɲ*)		
	C1	C2	C3	C4	C5	C6
SR	X	X	X	X	-	-
C	X	X	X	-	-	-
E	-	X	X	-	-	-
CO	-	X	X	-	-	X
L	-	-	-	-	X	-

Definition 3: A particular occupational risk (R) belongs to the set of NER if and only if its components configure at least one ordered pair (r, c) that belong to the subset of all ordered pairs that satisfy the conditions that can define a new risk (Ɲ) and at least one other ordered pair (r, c) belonging to the subset of all ordered pairs that satisfy the conditions that can define an increasing risk (Ɨ), which can be expressed as (4).

$$R \in NER \leftrightarrow \exists (r, c) \in \mathbb{N} \wedge \exists (r, c) \in \mathbb{I} \quad (4)$$

Thus, NER model (4) allows characterizing a risk in accordance with the component structure given by Eq. (1), which in turn confer to the risk the new and increased qualities of interest.

3. Results and discussion

3.1. Regulation analysis

The normative evolution over the last years in the Spanish construction sector has generated in the industrial building the appearance of new requirements, and consequently the development of new constructive technologies and new equipment and materials that have been incorporated into the designs and the subsequent execution.

3.1.1. The Regulation of Fire Safety in Industrial Establishments (FSRIE)

Spanish Industrial Subsector had not any requirements about fire safety for industrial plants with the exception of some local regulations, specific process or requirements of owners. In 2004, the FSRIE was published by the Royal Decree 2267/2004 [12]. This law regulates the conditions of design, the active and passive protection measures against fires for the industrial processes. These requirements are based on the type of establishment and the level of intrinsic risk.

Passive protection measures include the stability of the structure of buildings (pillars and beams). The structure of many industrial buildings is made of metallic profiles of rolled steel. These profiles have a bad behavior against the fire, so they need to apply a series of intumescent products in order to obtain the required fire stabilities (depending on the exposure to fire and the profile mass). Depending on the type of building and the level of intrinsic risk the fire stabilities can be from 15 minutes to 240 minutes. The lower fire stabilities can be achieved with intumescent paints (15-30 minutes) but for greater stabilities or even for low stabilities (since their application is more economically competitive) other products such as mortars of perlite-vermiculite or rock wool mortars are more common.

These are dry mortars that are mixed with water and projected by a pump and a hose onto the surface of the elements to be ignited. This type of mortars, although their datasheets indicate that they are made with non-toxic products or pathogens, can generate both discomfort on workers' skin. These discomfort, depending on the sensitivity of workers can cause eczemas or even some form of dermatitis, so it is necessary to use personal protective equipment to avoid contact with the skin.

Other passive protection measure that it is mandatory for some risk levels and voluntary for other plants (in order to reduce the requirement of fire stability of the supporting structures) are smoke ventilators in case of fire (Section 7 Annex II RD 2267/2004). These systems are composed of a control system associated to the fire detection system that drives some smoke ventilators located on the higher area of roof of industrial buildings. In many industrial plants, according to the criteria of the municipal technicians or the application of the residential rules, some fire active measures were installed, as fire hydrants (both internal and external). The FSRIE, according to the level of intrinsic risk and the type of industrial building, establishes the mandatory installation of a network of automatic fire sprinklers. This sprinkler network consists of a reservoir, a pump group and a network of pipes with the sprinklers.

3.1.2. The Technical Building Code (TBC)

The appearance of the TBC in 2006 [13] involved the inclusion of industrial buildings within the scope of application of the different basic documents. This regulation introduces requirements for justification in the design of the industrial plant of such important aspects as thermal conditioning, acoustic conditioning or safety of use.

Among these new requirements, must be highlighted aspects described in the Basic Document Energy Saving (BD-ES), part 4: Minimum solar contribution of domestic hot water and part 5: Minimum photovoltaic contribution of electric energy. The BD ES-4 requires a minimum contribution of solar energy for the generation of domestic hot water. Depending on the total demand of the building and the geographical area, the contribution ranges from 30 to 70% of the total contribution. The BD ES-5 requires a photovoltaic solar installation when the surface of the building

exceeds 5,000 m2. The power of the installation depends on the surface of the building and the climatic zone where it is located.

3.1.3. The Regulation on Demolition and Construction Waste Management (RDCWM)

In 2008, Royal Decree 105/2008 [14] was promulgated to regulate the production and management of construction and demolition waste (DCW). This regulation aims to promote the reuse, recycling and assessment of waste, in short, aims to promote proper management of demolition and construction resources. This law, in its article 5.5, establishes the obligatory of the in situ separation of certain fractions when they exceed a certain amount in the overall of the work. This amount is 8 tons for concrete, 40 tons for bricks and ceramic materials, 2 tons for metal, 1 ton for wood, 1 ton for glass and 0.5 tons for plastic, paper and cardboard.

The risks associated with demolition and construction waste depend mainly on the hazardousness of the chemicals from which they are derived and which may be contained in the DCWs and in the empty containers of these products. Among the chemicals that can be found under construction are cement, concrete and mortar additives, plasters, disintegrating agents, polyurethanes, fuels, detonators and explosives, paints and varnishes, solvents, bituminous products, adhesives, resins and silicones and lubricating oils.

4. Introduction

4.1. Characterization

According to the model of NER described at the section 2.1 main risks as consequence of the new construction process at industrial subsector are identified, described and characterized in the Table 2.

Table 2. Identification and Characterization of NERs at industrial subsector.

Nº NER	DESCRIPTION			
N1	Falls from different levels during the installation of smoke ventilators			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Installation of smoke ventilators at the roofs of the industrial buildings	Collective fall protection systems are not used Personal protective equipment is not used Information and training missing	Falls from different levels	Serious injuries and/or death	Increase of the time of the workers over the roofs Increase of the number of workers
The installation of smoke ventilators has been become in a mandatory action for many industrial activities from 2004, so it can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).				
Nº NER	DESCRIPTION			
N2	Falls from different levels during the installation of solar thermal panels			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Installation of solar thermal panels at the roofs of the industrial buildings	Collective fall protection systems are not used Personal protective equipment is not used Information and training missing	Falls from different levels	Serious injuries and/or death	Increase of the time of the workers over the roofs Increase of the number of workers
The installation of solar thermal panels has been become in a mandatory action for many industrial activities from 2006, so it can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).				

Nº NER	DESCRIPTION			
N3	Falls from different levels during the installation of solar photovoltaic panels			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Installation of solar photovoltaic panels at the roofs of the industrial buildings	Collective fall protection systems are not used Personal protective equipment is not used Information and training missing	Falls from different levels	Serious injuries and/or death	Increase of the time of the workers over the roofs Increase of the number of workers

The installation of solar photovoltaic panels has been become in a mandatory action for many industrial activities from 2006, so it can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N4	Falls from different levels during the installation of sprinklers			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Installation of sprinklers under the roofs of industrial buildings	Personal protective equipment is not used Information and trainingmissing Lack of maintenance of scissors platforms	Falls from different levels	Serious injuries and/or death	Increase of the time of the workers over the scissor platforms Increase of the number of workers

The installation of sprinklers has been become in a mandatory action for many industrial activities from 2004, so it can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N5	Falls from different levels during the application of intumescent products over the metallic profiles			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Application of intumescent products over the metallic profiles of industrial buildings	Personal protective equipment is not used Information and training missing Lack of maintenance of scissors platforms	Falls from different levels	Serious injuries and/or death	Increase of the time of the workers over the scissor platforms Increase of the number of workers

Theapplication of intumescent products over the metallic profiles has been become in a mandatory action for many industrial activities from 2004, so it can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N6	Accidents by scissor platforms during the installation of sprinklers			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Scissors platforms or vehicles in movement	Lack of signaling Information and training missing	Accidents and/or knocks with vehicles in movement	Minor injuries (hits, shocks, etc.) Serious injuries and/or death	Increase of the time of the workers or/and number of workers over the scissor platforms

The increase of circulation of scissor platforms during the construction of industrial buildings as a consequence of the installation of sprinklers can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N7	Accidents by scissor platforms during the application of intumescent products over the metallic profiles			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)

Scissors platforms or vehicles in movement	Lack of signaling Information and training missing	Accidents and/or knocks with vehicles in movement	Minor injuries (hits, shocks, etc.) Serious injuries and/or death	Increase of the time of the workers or/and number of workers over the scissor platforms

The increase of circulation of scissor platforms during the construction of industrial buildings as a consequence of the application of intumescent products over the metallic profiles can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N8	Exposure to intumescent products during the application of intumescent products over the metallic profiles			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Intumescent products	Personal protective equipment is not used Information and training missing	Diseases	Dermatitis or skin condition, eye irritations or diseases of respiratory ways	Increase of the time of the workers or/and number of exposed workers

The exposure to intumescent products as a consequence the application over the metallic profiles has been become in a mandatory action for many industrial activities from 2004, so it can be considered as a NER that affects the source of risk (C1), the likelihood of exposure (C5) and the consequences over the health of the workers (C6).

Nº NER	DESCRIPTION			
N9	Exposure to chemical products during the waste management activities			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Chemical products (including packaging)	Personal protective equipment is not used Information and training missing	Diseases	Dermatitis or skin condition, eye irritations or diseases of respiratory ways	Increase of the time of the workers or/and numberof exposed workers

The activities of waste management has been increased for construction sites from 2008, so the exposure to chemical products can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N10	Blows and cuts with materials during the waste management activities			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Materials and waste of the construction process	Personal protective equipment is not used Information and training missing Lack of cleanliness	Blows and cuts of the workers	Minor injuries (hits, shocks, etc.)	Increase of the time of the workers or/and number of exposed workers

The activities of waste management has been increased for construction sites from 2008, so the blow and cuts with waste of materials can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

Nº NER	DESCRIPTION			
N11	Overwhelming during the waste management activities			
Source of Risk (SR)	Causes (C)	Events (E)	Consequences (CO)	Likelihood (L)
Materials and waste of the construction process	Information and training missing Personal protective equipment is not used	Overwhelming of the workers	Minor injuries (low back pain, etc.)	Increase of the time of the workers or/and number of exposed workers

The activities of waste management has been increased for construction sites from 2008, so the overwhelming during the waste management activities can be considered as a NER that affects the source of risk (C4) and the likelihood of exposure (C5).

5. Conclusions

Over the last few years, regulatory framework have led to the emergence of new requirements in the industrial sector, resulting in the development of new construction technologies and new equipment and materials that have been incorporated into the designs and subsequent execution.

The emergence of these NERs involves a risk assessment in the documentation of prevention of occupational hazards of projects and contractors and subcontractors, as well as the use of a series of collective and individual protection measures during the execution of the works. One way to educate workers about NERs would be to develop procedural manuals that would inform and train about appropriate work procedures.

This work, and in the area of industrial building, should be supplemented by a study of NERs that may have appeared as a consequence of the profile of workers in this type of construction or as a consequence of psychosocial factors arising from the adjustment of the subsector due to the economic crisis.

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References

[1] EU-OSHA, 2013. European Risk Observatory. Available at: <https://osha.europa.eu/en/riskobserva tory>.
[2] E. Rial, et al., 2005. Priorities for occupational safety and health research in the EU-25. Available at: https://osha.europa.eu/en/publications/reports/6805648.
[3] M.V. Achter, A. Degrand-Guillaud 2006. Promoción de la investigación sobre seguridad y salud en el trabajo en la Unión Europea: Promoción de la investigación sobre SST en la Unión Europea. Available at: http://bookshop.europa.eu/es/promocion-de-la-investigacion-sobre-seguridad-y-salud-en-el-trabajo-en-la-union-europea-pbTE7506906/downloads.
[4] K. Savolainen, K. Sas,15(2006) 7-7.
[5] Instituto Nacional de Seguridad e Higiene en el Trabajo, 2007, Estrategia Española de Seguridad y Salud Laboral 2007-2012. Available at: http://www.insht.es/InshtWeb/Contenidos/Instituto/Estrategia_Seguridad_Salud/Doc.Estrategia%20actualizado%202011%20ultima%20modificacion.pdf
[6] M. Bartolomé, C. Fernández, S. Prieto, Sánchez, Rev. Univ. Ciencias del Trab. 8 (2007) 341-356.
[7] F. Brocal, M.A. Sebastián, Procedia Eng., 100 (2015) 1150-1159.
[8] F. Brocal, M.A. Sebastián, Procedia Eng. 100 (2015) 887-894.
[9] F.Sanz, Estudio sobre Riesgos Laborales Emergentes en el Sector de la Construcción. Revisión Bibliográfica, Madrid: Instituto Nacional de Seguridad e Higiene en el Trabajo, 2013.
[10] European Committee for Standardization (CEN), 2010, Risk Management. Risk Assessment Techniques, EN 31010:2010, Brussels.
[11] International Organization for Standardization (ISO), 2009, Risk Management – Principles and Guidelines, ISO 31000:2009, Geneva.
[12] España, Real Decreto 2267/2004, de 3 de Diciembre, por el que se aprueba el Reglamento de Seguridad contra incendios en los establecimientos industriales. Boletín Oficial del Estado, núm. 303, 41194-41255.
[13] España, Real Decreto 314/2006, de 17 de Marzo, por el que se aprueba el Código Técnico de la Edificación. Boletín Oficial del Estado, núm. 74, 11816-11831.
[14] España. Real Decreto 105/2008, de 1 de Febrero, por el que se regula la producción y gestión de los residuos de construcción y demolición. Boletín Oficial del Estado, núm. 38, 7724-7730.