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Assessing concerns of interested parties when predicting the significance of environmental impacts related to the construction process of residential buildings

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ABSTRACT

The most common challenges and obstacles encountered by construction organizations during the process of implementing and using environmental management systems are related to the inherent peculiarities of the construction sector. Several studies have shown that one of the issues involving the greatest level of uncertainty is the identification and assessment of environmental impacts. In order to improve the identification of the significance of environmental impacts of construction projects and sites, which will lead to greater efficiency and robustness in environmental management systems, this paper extends the systematic approach for identifying and assessing potential adverse environmental impacts at the pre-construction stage presented in Gangolells et al. (2009) by introducing the assessment of the concerns of interested parties. By considering concerns amongst internal and external interested parties, one can assess the significance of environmental impacts taking into account not only the severity of the impacts but also local perceptions and international challenges, thereby ensuring that the determination of the impacts' significance is appropriate to the particular socioeconomic and biophysical environments surrounding construction sites. In order to quantitatively measure concerns among internal and external interested parties for each of the 37 environmental impacts related to a construction project, we developed corresponding indicators and assessment scales with the help of a panel of experts. A series of χ^2 tests conducted over 76 new-start construction projects clearly revealed that the severity of environmental impacts is not correlated with the concerns of interested parties. The development of a formal quantitative method and the subsequent definition of a threshold make it possible to obtain advance knowledge of the significance—and therefore the acceptability—of each potential environmental impact for a particular construction project. A total score for each construction project alternative is also obtained, so the improved methodology provides a consistent basis

for comparing construction companies and construction sites. Finally, two case studies are presented in order to demonstrate the benefits of the improved methodology.

Keywords:
environmental impact, impact significance determination, environmental management, environmental management system, building, construction process.

1. INTRODUCTION

According to Griffith et al. [1], quality management systems have successfully been implemented by contractors over the last 25 years, formerly as BS 5750:1978 [2] and in recent years by ISO 9001:2000 [3] and ISO 9001:2008 [4]. The construction industry has the third-highest number of ISO 9000 certificates among all industrial sectors worldwide [5]. Construction-related firms accounted for 7% of all certified companies in all industrial sectors worldwide in 2000 [6], with approximately 28,600 construction-related companies having a quality certificate. In the construction industry, environmental certification ISO 14001: 1996 [7] or ISO 14001:2004 [8] is relatively infrequent compared with ISO 9001 [5], for which 9,095 certificates were awarded in 2006 [9]. According to official data provided by the European Commission in February 2009, an Eco-Management and Audit Scheme (EMAS) had been adopted and implemented by 216 construction organizations [10].

Environmental management systems are most common among manufacturing facilities, which are relatively stable over time and have a longer and more extensive history of environmental regulation [11]. The low environmental certification rates in the construction sector are attributed to the uncertainty caused by the application of traditional standards-based management systems at the project level [1]. Unlike ordinary manufacturing industries, the construction industry makes complex [12] and unique products and includes a wide variety of construction techniques and systems. Moreover, in the construction sector the place of production must necessarily be the place where the product is going to be used [13]. The construction industry typically involves short construction periods and is largely exposed to outdoor conditions. For this reason, according to Hoyle [14], systems are frequently applied to isolated parts of organizations in the construction sector rather than to whole organizations, and their efficacy has therefore been questioned.

Environmental aspects are the focus of environmental management systems, since a company implementing ISO 14001:2004 [8] builds the system to address these aspects [15]. Various indicators point to the fact that a dominant aspect of the implementation and upkeep of an environmental management system is associated with the planning stage, especially as relates to the subsystem for identifying and assessing environmental aspects and impacts [16].

Having recognized environmental impact identification and assessment as a central feature in the development of environmental management systems [16] and taking into account that the identification and assessment of environmental impacts is considered to be one of the issues involving the highest levels of uncertainty [17], the purpose of this paper is to improve the assessment of construction-related environmental impacts within the framework of the implementation of environmental management systems in construction companies. Improving the identification of the significance of environmental impacts of construction projects and siteswill lead to increased efficiency and robustness in environmental management systems. In addition, the environmental performance of construction projects and sites will be improved given that the relevance of each environmental aspect at a particular site is predicted prior to the construction stage. Significant impacts are highlighted in advance and it is possible to plan a range of on-site measures for mitigating them.Gangolells et al. [18] significantly contributed to overcoming the main obstacles related to the process of implementing environmental management systems in the construction sector by developing an innovative methodology for predicting the severity of the environmental impacts associated with the construction of new residential buildings. However, as mentioned in ISO 14001:2004 [8], the concerns of interested parties should be considered in the assessment of environmental impacts. The assessment of the interested and affected parties is even more important in highly site-based industries, such as the construction industry, where the context may be multivariate in nature. Assuming that the significance of an environmental impact depends not only on its severity but also on the degree of sensitivity to environmental impacts of habitats, species and communities within the geographical areas affected by construction projects and society as a whole, the aim of this research is to extend the approach presented in Gangolells et al. [18] for identifying and assessing potential adverse environmental impacts related to the construction process of residential buildings by introducing the assessment of the concerns of interested parties.

This article starts by exploring the methodological framework for the identification and assessment of environmental impacts established by standards ISO 14001:2004 [8] and ISO 14004:2004 [19]. Taking into account that both standards highlight the need to better understand how the concerns of interested parties actually modify the significance of an environmental impact, this paper includes this extra criterion in the framework proposed by Gangolells et al. [18]. So as to quantitatively measure the concerns of internal and external interested parties for each of the 37 environmental impacts related to the construction process, particular attention is paid to the development of indicators and assessment scales. The results of χ^2 tests of independence conducted over 76 new-start construction projects show no relationship between severity and the concerns of interested parties. After a formal quantitative method is proposed to determine and rank the significance of each environmental impact in a particular construction project on the basis of its severity and the concerns of interested parties, the level of acceptability of a potential environmental impact is established. Two case studies are then presented to demonstrate the benefits of the improved methodology. Finally, conclusions are presented and recommendations for future research are made.

2. ENVIRONMENTAL IMPACT ASSESSMENT WITHIN THE SCOPE OF ISO 14001:2004

The ISO 14001:2004 [8] standard requires a planning process to identify and assess the environmental aspects that characterize a company's activities in order to later implement environmental programs addressing those environmental impacts found to be significant. As stated by Burdick [20] and Ghisellini and Thurston [21], the process of assessing and identifying the environmental aspects and impacts and the methodology used to rank the significance of the aspects are fundamental stages within the process of implementing environmental management systems. In fact, assessing the significance of environmental impacts is the basis for structuring the planning phase and for organizing the environmental management system as a whole [16]. Environmental impacts not considered to be significant are not currently managed by the environmental management system.

Previous studies such as those provided by Põder [17], Ghisellini and Thurston [21], Zobel et al. [22], Babakri et al. [23] and Zobel and Burman [24] have revealed that the identification and assessment of environmental aspects and impacts is the most problematic issue in implementing ISO 14001:2004 [8]. In fact, the methodological framework established by standards ISO 14001:2004 [8] and ISO 14004:2004 [19] gives only general principles for the assessment of environmental aspects [17]. ISO 14001:2004 [8] does not provide a rigorous definition of significant aspects [16] and literally states that 'although there is no single method for determining significant environmental impacts, the method used should provide consistent results and include the establishment and application of assessment criteria, such as those related to environmental matters, legal issues and the concerns of internal and external interested parties'. Unfortunately, ISO 14001:2004 [8] does not provide any further explanation as to how these components of significance should be interpreted [17]. Therefore, the ISO 14001:2004 [8] standard grants companies a great degree of freedom in establishing their overall environmental impact, leaving significant room for adaptation and indeed interpretation [15].

ISO 14001:2004 [8] defines environment as 'a surrounding in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelations'. Hence, the terms 'environment' and 'environmental impact' have broad meaning in the context of environmental management, encompassing both biophysical and socioeconomic environments [17]. For this reason, the ISO 14001:2004 [8] standard explicitly recommends taking into account the concerns of interested parties when assessing the significance of environmental impacts. ISO 14004:2004 [19] defines interested party as 'a person or group concerned with or affected by the environmental performance of an organization'. Therefore, effective impact significance determination must include a thorough understanding of contextual factors such as society as a whole, the affected region, the affected interests and the locality [25]. Making significance determinations context-dependent [26] is even more necessary in construction organizations because the objects of construction are rooted in place [27]. Taking into account that interested parties vary depending on the place of production, Ghisellini and Thurston [21] also recommended including stakeholder concerns when assessing the significance of environmental aspects in construction organizations. Along the same lines, research carried out by Glass and Simmonds [28] recognized that construction projects may experience different challenges due to differences in site, locality, parties involved and tolerance levels that make it difficult to predict and address environmental impacts. The Environmental Impact Assessment or EIA Directive (Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment [29] amended by Council Directive 97/11/EC [30] and Directive 2003/35/EC [31]) also mandates consultation within interested parties when assessing the effects of certain public and private projects on the environment. Although the EIA screening process varies significantly among countries [32], residential construction projects are hardly ever subjected to an EIA (Table 1). For example, the Spanish EIA system established by the Legislative Royal Decree 1/2008 of 11 January 2008, passing the consolidated text of the Law on the Environmental Impact of Projects [33], has no thresholds for residential developments, so they will only require an EIA when they are placed on natural reserves or in non-urban areas in the case of large developments (over 100 ha), which represents a very small proportion of new-start residential construction projects.

Country	**Residential developments**
Germany	> 10 ha
Holland	> 2,000 dwellings
Portugal	> 500 dwellings
Spain	n.t.
Bulgaria	n.t.
Switzerland	n.t.
Latvia	n.r.
Tunisia	> 20 ha
Niger	n.t.
Chile	> 80 dwellings
Mexico	n.t.
Vietnam	n.t.

n.t.: no thresholds specified, n.r.: non-regulated activity.

Table 1. Screening criteria for residential developments in the EIA framework. Source: Martínez Orozco [32].

In a thorough review of the international literature, few references were found that address, in depth, the methodological subjects associated with the implementation of the environmental impact assessment process within the scope of an ISO 14001:2004 [8] environmental management system for SMEs [16]. This leads to the conclusion that research on the identification and assessment of environmental aspects in the ISO 14001 context is lacking [24]. According to Põder [17], methodological issues related to the assessment of environmental aspects have been largely overlooked, but this situation is even worse in the construction sector, where the diversity of construction activities and the uniqueness of each construction project lead to multiple environmental impacts, thereby hindering their assessment and quantification [34]. An extensive review of the previous studies addressing methodological subjects related to the assessment of the significance of environmental impacts in construction projects found a limited number of quantitative approaches, namely those provided by Gangolells et al. [18], Chen et al. [35], Chen et al. [36], Chen et al. [37], Cheung et al. [38], Tam et al. [39], Chen et al. [40], Dione et al. [41], Li et al. [42], Shen et al. [43], Tam et al. [44], Eom and Paek [45] and San-José and Garrucho [46]. However, most of these approaches were not designed to take into account the concerns of interested and affected parties. Only Dione et al. [41] partially filled this gap by defining three general components for environmental risks, namely the source of contamination, the receptor of the contamination (public, wildlife or environmental), and the pathway that introduces the contamination to the receptor. San-José and Garrucho [46] developed a system approach to the lifecycle environmental analysis of industrial buildings that considers four basic criteria: siting, energy consumption, water usage and material usage. These authors defined several criteria, subcriteria and indicators for considering alternative locations for an industrial plant that were mainly related to (i) industrial building localization and location, and (ii) visual and landscape impact.

Therefore, taking into account that the complexity inherent to construction sites has direct consequences on environmental impact assessment, additional attention should be devoted to establishing the roles and role interaction of interested and affected parties in determining the significance of construction project impacts in various settings. The importance of this task is enhanced by the fact that environmental management systems do not manage those environmental impacts not considered significant due to a failure to assess the interests, values and concerns of affected parties.

3. IDENTIFICATION AND ASSESSMENT OF THE SIGNIFICANCE OF ENVIRONMENTAL IMPACTS RELATED TO THE CONSTRUCTION PROCESS ACCORDING TO ISO 14001:2004

Gangolells et al. [18] presented an innovative methodology for identifying and assessing the severity of the environmental impacts associated with the construction of new residential buildings.

In this methodology, the impacts are measured according to their severity, which is related to the magnitude of the change or the size of the impact. However, as mentioned above, severity does not always equate with significance. In fact, the significance of environmental impacts is related to the importance placed (by experts or by the public) on the magnitude of the impact [47]. Therefore, as mentioned in the ISO standard itself and in Gangolells et al. [18], the concerns of interested parties should be considered when the significance of environmental impacts is assessed.

3.1. IDENTIFICATION OF ENVIRONMENTAL IMPACTS RELATED TO THE CONSTRUCTION PROCESS

ISO 14004:2004 [8] states that, when establishing significance criteria, an organization should consider (i) environmental criteria, (ii) applicable legal requirements, and (iii) the concerns of internal and external interested parties. Gangolells et al. [18] carefully analysed environmental matters and concluded that some environmental components of significance did not depend on each building site and therefore could be used to determine environmental aspects related to the construction process (Fig. 1). Therefore, the scale of the impact, its probability of occurrence and its duration were used in an exhaustive preliminary analysis with a process-oriented approach [18], which obtained 37 different environmental impacts related to the construction process (Table 2).

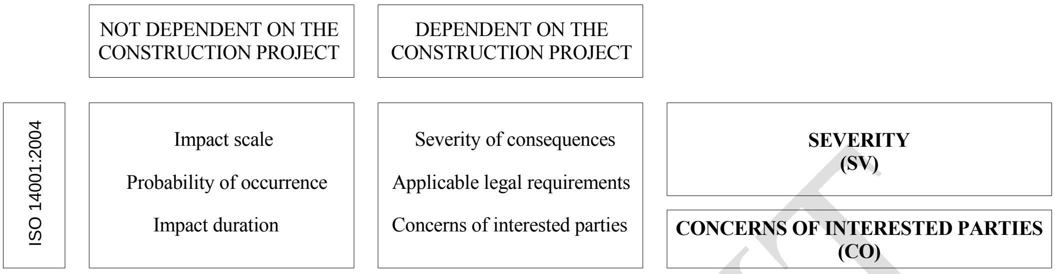

Figure 1. Overview of the components of significance for identifying and assessing environmental impacts related to the construction process according to ISO 14001:2004. Source: drawn up by the authors.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
ATMOSPHERIC EMISSIONS						
AE-1	Generation of greenhouse gas emissions due to construction machinery and vehicle movements.	Volume of excavated material per m^2 of floor area $[m^3/m^2] \cdot C + 0.3 \cdot N$; where C=1.2 when special machinery is needed, otherwise C=1.0 and N is the number of power generators.	External interested parties.	-	-	All cases.
AE-2	Emission of VOCs and CFCs.	% of synthetic paints and varnishes.	External interested parties.	-	-	All cases.
WATER EMISSIONS						
WE-1	Dumping of water resulting from the execution of foundations and retaining walls.	Quantity of thixotropic fluid per m^2 of floor area $[kg/m^2]$.	External interested parties.	Existence of an in-situ waterproof settling basin or watertight tank.	Connection to sewage system, dumping in septic tank and/or existence of previous treatment.	Direct dumping to the natural or urban environment.
WE-2	Dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids.	Quantity of concrete per m^2 of floor area $[m^3/m^2]$.	External interested parties.	Existence of an in-situ waterproof settling basin or watertight tank.	Connection to sewage system, dumping in septic tank and/or existence of previous treatment.	Direct dumping to the natural or urban environment.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
WE-3	Dumping of sanitary water resulting from on-site sanitary conveniences.	Average number of workers per day.	External interested parties.	Connection to sewage system.	Dumping in septic tank and/or existence of previous treatment.	Direct dumping to the natural or urban environment.
WASTE GENERATION						
WG-1	Generation of excavated waste material during earthworks.	Volume of excavated material per m^2 of floor area [m^3/m^2].	External interested parties.	In-situ reuse or delivery to an authorized manager for future reuse or recycling.	Delivery to an authorized manager for future disposal, or delivery to an authorized manager with unknown final waste destination.	On-site waste management unawareness.
WG-2	Generation of municipal waste by on-site construction workers.	Average number of workers per day.	External interested parties.	Selective waste collection and delivery to an authorized manager for future reuse or recycling.	Selective waste collection and delivery to an authorized manager for future disposal or delivery to an authorized manager with unknown final waste destination.	Non-selective waste collection and delivery to an authorized manager or on-site waste management unawareness.
WG-3	Generation of inert waste.	Floor area [m^2].	External interested parties.	In-situ reuse or selective waste collection and delivery to an authorized manager for future reuse or recycling.	Selective waste collection and delivery to an authorized manager for future disposal or delivery to an authorized manager with unknown final waste destination.	Non-selective waste collection and delivery to an authorized manager or on-site waste management unawareness.
WG-4	Generation of ordinary or non-special waste (wood, plastic, metal, paper, cardboard or glass).	Floor area [m^2].	External interested parties.	In-situ reuse or selective waste collection and delivery to an authorized manager for future reuse or recycling.	Selective waste collection and delivery to an authorized manager for future disposal or delivery to an authorized manager with unknown final waste destination.	Non-selective waste collection and delivery to an authorized manager or on-site waste management unawareness.

ENVIRONMENTAL ASPECT		**SV[1]**	**CONCERNS**	**CO[2] = 1**	**CO[2] = 3**	**CO[2] = 5**
WG-5	Generation of special (potentially dangerous) waste.	Floor area [m^2].	External interested parties.	Selective waste collection and delivery to an authorized manager.	-	Non-selective waste collection and delivery to an authorized manager or on-site waste management unawareness.
SOIL ALTERATION						
SA-1	Land occupancy by the building, provisional on-site facilities and storage areas.	Site occupation per m^2 of floor area [m^2/m^2].	Internal interested parties.	The construction site perimeter does not affect the amount of free space for vehicle or pedestrian circulation or the number of available parking places.	The construction site perimeter invades the sidewalk, with more than 1.00 m of free space left for foot traffic, or the construction site perimeter affects the number of available parking places on the road/street, with 2.75 m of free space left for vehicle circulation on one-way roads or 6.00 m on two-way roads.	The construction site perimeter invades the sidewalk, with less than 1.00 m of free space left for foot traffic, or the construction site perimeter affects the road/street, with less than 2.75 m of free space left for vehicle circulation on one-way roads or less than 6.00 m on two-way roads.
SA-2	Use of concrete release agent at the construction site.	Use of concrete.	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
SA-3	Use of cleaning agents or surface-treatment liquids at the construction site.	% of facing brick closure. % of the floor area having discontinuous ceramic and/or stone surfaces.	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
SA-4	Dumping derived from the use and maintenance of construction machinery.	Volume of excavated material per m^2 of floor area $[m^3/m^2]$ + 6E-5·floor area $[m^2]$.	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
SA-5	Dumping of water resulting from the execution of foundations and retaining walls.	Quantity of thixotropic fluid per m^2 of floor area $[kg/m^2]$.	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
SA-6	Dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids.	Quantity of concrete per m^2 of floor area [m^3/m^2].	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
SA-7	Dumping of sanitary water resulting from on-site sanitary conveniences.	Average number of workers per day.	External interested parties.	Urban areas, industrial parks and large waterproofed areas.	Non-protected rural areas away from water courses.	Rural areas near water courses, areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
RESOURCE CONSUMPTION						
RC-1	Water consumption during the construction process.	Water consumption per m^2 of floor area [m^3/m^2].	External interested parties.	Use of rainwater or tap water.	Use of water tankers or water from rivers or wells.	Use of water from rivers or wells in drought-affected areas.
RC-2	Electricity consumption during the construction process.	Floor area [m^2].	External interested parties.	Use of electricity from the grid.	-	Use of power generators.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
RC-3	Fuel consumption during the construction process.	Volume of excavated material per m^2 of floor area $[m^3/m^2] \cdot C + 0.3 \cdot N$; where C=1.2 when special machinery is needed, otherwise C=1.0 and N is the number of power generators.	External interested parties.	-	-	All cases.
RC-4	Raw materials consumption during the construction process.	Weight of structural floors, foundations, facades, partition walls, pavements and roofs per m^2 of floor area $[kg/m^2]$.	External interested parties.	Recycled content in raw materials greater than 50%.	Recycled content in raw materials between 5 and 50%.	Recycled content in raw materials not is planned or non-existence of information in this regard.
LOCAL ISSUES						
L-1	Dust generation in activities with construction machinery and transport.	Volume of excavated material per m^2 of floor area $[m^3/m^2]$.	Internal / external interested parties.	Distance to a neighbouring town centre greater than 5,000 m.	Distance to a neighbouring town centre between 1,000 and 5,000 m.	Construction site located in or less than 1,000 m from an urban area, or in an area with legal protection, or in another area that, due to its unique nature (i.e. natural, archaeological, etc.), must be specially protected.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
L-2	Dust generation in earthworks activities and stockpiles.	Volume of excavated material per m^2 of floor area [m^3/m^2].	Internal / external interested parties.	Distance to a neighbouring town centre greater than 5,000 m.	Distance to a neighbouring town centre between 1,000 and 5,000 m.	Construction site located in or less than 1,000 m from an urban area, or in an area with legal protection, or in another area that, due to its unique nature (i.e. natural, archaeological, etc.), must be specially protected.
L-3	Dust generation in activities with cutting operations.	% of facing brick closure. % of the floor area having discontinuous ceramic and/or stone surfaces.	Internal / external interested parties.	Distance to a neighbouring town centre greater than 5,000 m.	Distance to a neighbouring town centre between 1,000 and 5,000 m.	Construction site located in or less than 1,000 m from an urban area, or in an area with legal protection, or in another area that, due to its unique nature (i.e. natural, archaeological, etc.), must be specially protected.
L-4	Operations that cause dirtiness at the construction site entrances.	Floor area [m^2].	Internal interested parties.	Construction site located on low-traffic road.	Construction site located on medium-/high-traffic road.	Construction site located in an urban area.
L-5	Generation of noise and vibrations due to site activities.	Time of activity, use of special machinery (road roller, graders and compactors, etc.).	Internal / external interested parties.	Isolated construction sites or construction sites located in industrial areas or areas affected by noise easements. C or IV-V type zones.	Construction sites located in residential or commercial areas. B or II-III type zones.	Construction site located in high-acoustic-comfort areas (i.e. urban areas, areas near schools or hospitals, areas of special zoological interest, etc.). A or I type zones.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
L-6	Landscape alteration by the presence of singular elements (cranes).	Number of cranes.	Internal interested parties.	Urban area without immediate historical/artistic buildings.	Rural areas not registered as special interest areas.	Urban areas adjacent to historical/artistic buildings, areas with legal protection, or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
TRANSPORT ISSUES						
T-1	Increase in external road traffic due to construction site transport.	Floor area [m^2].	Internal interested parties.	Construction site located on low-traffic-density road.	-	Construction site located on medium-/high-traffic-density road.
T-2	Interference in external road traffic due to the construction site.	Number of traffic cuts in non-instantaneous periods of time.	Internal interested parties.	Construction site located on low-traffic-density road.	Construction site located on medium-/high-traffic-density road, with 2.75 m of free space left for vehicle circulation on one-way roads, or 6 m on two-way roads.	Construction site located on medium-/high-traffic-density road, with less than 2.75 m of free space left for vehicle circulation on one-way roads, or less than 6 m on two-way roads.
EFFECTS ON BIODIVERSITY						
B-1	Operations with vegetation removal (site preparation).	Site occupation per m^2 of floor area [m^2/m^2].	External interested parties.	The affected area is located inside the construction site perimeter or the affected area is located outside the construction site perimeter when there is no vegetation.	The affected area is located outside the construction site perimeter when there is vegetation.	Areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
B-2	Operations with loss of edaphic soil (site preparation).	Site occupation per m^2 of floor area [m^2/m^2].	External interested parties.	The affected area is located inside the construction site perimeter or the affected area is located outside the construction site perimeter when there is no edaphic soil.	The affected area is located outside the construction site perimeter when there is edaphic soil.	Areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
B-3	Operations with high potential soil erosion (unprotected soils as a consequence of earthworks).	Site occupation per m^2 of floor area [m^2/m^2].	External interested parties.	The affected area is located inside the construction site perimeter.	The affected area is located outside the construction site perimeter.	Areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
B-4	Opening construction site entrances with soil compaction.	Length of the entrance to the site [m].	External interested parties.	The affected area is located inside the construction site perimeter.	The affected area is located outside the construction site perimeter.	Areas with legal protection or other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.
B-5	Interception of riverbeds, integration of riverbeds in the development, water channelling and stream water cutoff.	Number of contact points with riverbeds.	External interested parties	Existence of artificial channelling or non-existence of natural riverbeds.	Natural riverbeds in non-protected areas.	Natural riverbeds in areas with legal protection or in other areas that, due to their unique nature (i.e. natural, archaeological, etc.), must be specially protected.

ENVIRONMENTAL ASPECT		SV[1]	CONCERNS	CO[2] = 1	CO[2] = 3	CO[2] = 5
INCIDENTS, ACCIDENTS AND POTENTIAL EMERGENCY SITUATIONS						
AC-1	Fires at areas for storing flammable and combustible substances.	Floor area [m^2].	Internal / external interested parties.	Isolated construction site (distance to nearby occupied buildings, forested areas or other high-fire-risk areas is greater than 500 m).	Distance to nearby occupied buildings, forested areas or other high-fire-risk areas is between 100 and 500 m.	Distance to nearby occupied buildings, forested areas or high-fire-risk areas is less than 100 m.
AC-2	Breakage of underground pipes (electric power cables, telephone lines, water pipes, or liquid or gaseous hydrocarbon pipes).	Site occupation per m^2 of floor area [m^2/m^2].	Internal / external interested parties.	Construction site is located in an urban area with less than 100 inhabitants.	Construction site is located in an urban area with more than 100 inhabitants, with a distance to nearby occupied buildings, forested areas or other high-fire-risk areas and basic services for the community (fire stations, hospitals, airports, etc.) of between 100 and 500 m.	Construction site is located in an urban area with more than 100 inhabitants, with a distance to nearby occupied buildings, forested areas or other high-fire-risk areas and basic services for the community (fire stations, hospitals, airports, etc.) of less than 100 m.
AC-3	Breakage of receptacles with harmful substances. Storage tanks for dangerous products.	Floor area [m^2].	Internal / external interested parties.	Construction site is located in a sparsely populated area and more than 100 m from a riverbed or permeable soil.	Construction site is located in a sparsely populated area less than 100 m from riverbeds or permeable soils, or in a medium-density area.	Construction site is located in a high-population-density area, or in an area with legal protection, or in another area that, due to its unique nature (i.e. natural, archaeological, etc.), must be specially protected.

[1] SV: Indicators for calculating the severity of the environmental impacts, taken from Gangolells et al. [18].
[2] CO: Concerns of interested parties.

Table 2. Evaluation of the concerns of interested parties regarding environmental aspects related to the construction process.

3.2. ASSESSMENT OF THE SEVERITY OF ENVIRONMENTAL IMPACTS RELATED TO THE CONSTRUCTION PROCESS

Once potential environmental impacts related to the construction process had been identified, the remaining components of significance related to environmental and legal matters that matched those depending on each specific building site (severity of consequences and applicable legal requirements) were used to establish the framework for assessing the severity of environmental aspects (SV) (Fig. 1). The impact severity parameter (SV) assesses the magnitude of each environmental aspect in quantitative terms. In order to include detailed criteria to help decision-makers determine the severity of environmental impacts, a four-interval scale with corresponding numerical scores was developed: non-existent impact, non-significant severity, marginally significant severity and extremely significant severity (Table 3).

Severity of environmental impacts (Sv_j)	**Score**
Non-existent impacts	0
Non-significant impacts	1
Marginally significant impacts	3
Extremely significant impacts	5

Table 3. Scoring system for severity (SV_j).
Source: Gangolells et al. [18].

To achieve a homogeneous outcome, numerical limits were established between non-existent impacts, non-significant impacts, marginally significant impacts and extremely significant impacts by conducting a statistical analysis of 55 new-construction projects [18]. As a starting point, it was considered that a high proportion of construction projects involve a marginally significant impact and thus a 68% [μ-σ, μ+σ] confidence interval was calculated for each environmental indicator [18]. If an environmental indicator is lower than μ-σ, the environmental impact is considered to be non-significant and if the environmental indicator is higher than μ+σ, the environmental impact is considered to be extremely significant [18]. Table 1 in Gangolells et al. [18] shows the significance limits for each environmental impact.

In response to the environmental standard's insistence upon the need to better understand how concerns of interested parties actually modify the significance of an environmental impact, the following subsection focuses on improving the process of assessing the significance of construction-related environmental impacts by introducing the assessment of the influence of interested and affected parties. If the severity of an environmental impact related to on-site noise generation is found to be important, it is essential to determine whether any receptor could be affected by excessive noise. Potentially sensitive receptors are obviously present if a project is undertaken in an urban area with schools or hospitals nearby. If a construction project is located in an area of special zoological interest, once again, potential receptors are present. In contrast, if a construction project is located in an industrial area or other area affected by a noise easement, the receptors, if any, will be much less sensitive. Although severity is important in all three of the aforementioned cases, the environmental management system should only conclude that the impact is significant in the first two cases and only in these cases should specific actions be taken by the construction company.

3.3. ASSESSMENT OF CONCERNS OF INTERESTED PARTIES

In order to include detailed criteria to help people determine how internal and external interested parties actually modify environmental impact significance (CO), a three-interval scale was developed: little/no concern to interested parties, secondary concern to all or most interested parties, and primary concern to all or most interested parties (Table 4). To help achieve a homogeneous outcome, numerical scores were established for each of the three categories.

Concerns of interested parties (CO_j)	**Score**
Little/no concern to interested parties	1
Secondary concern to all or most interested parties	3
Primary concern to all or most interested parties	5

Table 4. Scoring system for concerns of interested parties (CO_j).

The concerns of interested parties were classified according to a quantitative scale. In order to achieve effective assessment of environmental impacts, this scoring system was adjusted to the one established in Gangolells et al. [18], which is the context in which it will be used. In order to assess the concerns of interested parties for each environmental impact, a panel of experts from various professional fields related to both the environment and the construction industry were asked to develop indicators and corresponding assessment scales. The panel of experts was composed of two senior engineers working in environmental consultancy firms, two project managers working in construction companies and two environmentalists from a local non-governmental organization. The consultation panel also included two associate professors working at the Universitat Politècnica de Catalunya with a broad background in sustainable construction.

Although quantitative assessment indicators are more desirable [48], most of the indicators had to be qualitative, since numerical data related to the concerns of interested parties are generally not available at the pre-construction stage. Greater care and precision was employed in the description of the assessment scales in order to avoid relying on personal judgements and considerations. Table 2 shows the indicators developed and the corresponding assessment scales.

Interested parties are classified as internal or external, according to their dual nature. Internal interested parties comprise those neighbouring communities directly affected by a proposed project that may regard some of the identifiable environmental impacts as highly significant. Because construction projects are rooted in a particular place, the concerns of the surrounding community may differ from one place to the next. Failure to acknowledge the concerns of these interested parties may lead to complaints about the environmental performance of the construction organization and possibly legal actions, which can subsequently cause not only an increase in the overall cost but also delays in the progress of the construction project. External interested parties comprise the society as a whole, who may also consider certain environmental impacts to be highly significant. Effectively integrating the concerns of external interested parties represented by community associations, environmentalists, non-governmental organizations, the media, etc. will obviously lead to better determinations of environmental impact significance. Table 2 illustrates the differences between the concerns of internal interested parties and those of external interested parties. For some environmental impacts, internal and external interested parties may coexist.

3.3.1. DETERMINING INDICATORS FOR ASSESSING CONCERNS OF INTERNAL INTERESTED PARTIES

The concerns of internal interested parties include a wide range of issues derived from the direct influence of construction activities on neighbouring communities. Building construction projects may be disturbing to those living near the site. Occupancy of public thoroughfares by provisional on-site facilities and storage areas may either decrease the number of parking places on the street or cause road traffic restrictions, which can be a source of annoyance for the surrounding community. Pedestrians may also be bothered by on-site occupancy. Therefore, environment impact SA-1 (land occupancy by the building, provisional on-site facilities and storage areas) will be higher if the construction site perimeter affects the width of vehicle or pedestrian thoroughfares or the number of available parking places.

Pedestrians may also be bothered by the dirtiness of construction site entrances. The significance of environmental impact L-4 (operations that cause dirtiness at the construction site entrances) may vary depending on whether the construction site is located in an urban area and whether it is located on a low-, medium- or high-traffic road.

The increase in external road traffic due to construction site transport may also affect neighbouring communities. The significance of environmental impact T-1 (increase in external road traffic due to construction site transport) will be higher if the construction site is located on a medium- or high-traffic road than if it is located on a low-traffic road.

Environmental impact T-2 (interference in external road traffic due to the construction site) may also affect nearby people. The significance of this environmental impact will depend on where the construction site is located. If the site is located on a narrow road with a medium/high traffic density, the significance of environmental impact T-2 will be higher than if the site is located on a wider road with low traffic density.

Besides causing health risks for both the on-site workers and the surrounding people, dust generation can require increased cleaning for immediate neighbours. Therefore, the significance of environmental impacts L-1 (dust generation in activities with construction machinery and transport), L-2 (dust generation in earthworks activities and stockpiles) and L-3 (dust generation in activities with cutting operations) should be considered greater if the construction site is located in or near an urban area.

Noise and vibrations can also be disruptive for people living near the site. According to Ballesteros et al. [49], the annoyance caused is high due to the huge variability of noise levels and the large number of low-frequency components. The environmental impact L-5 (generation of noise and vibrations due to site activities) will be more significant if the construction site is located in high-acoustic-comfort areas than if it is isolated or located in an area affected by a noise easement (i.e. an industrial area).

Nearby people may also be affected by the unsightly appearance of a construction site, especially in highly valued settings such as urban areas with nearby historical/artistic buildings, areas with legal protection, or other areas that, due to their natural or archaeological uniqueness, are specially protected. In that case, the surrounding community may regard environmental impact L-6 (landscape alteration by the presence of singular elements) as a highly significant environmental impact. The significance of this environmental impact decreases if the construction site is located in an urban area without nearby historical/artistic buildings or in a rural area not registered as a special-interest area.

On-site incidents, accidents and potential emergency situations may also raise concerns amongst immediate neighbours. Indeed, environmental impacts AC-1 (fires at areas for storing flammable and combustible substances), AC-2 (breakage of underground pipes) and AC-3 (breakage of receptacles with harmful substances) refer to events that go beyond the physical boundaries of the construction organization. Significance assessments should reflect greater importance if a construction project is located in a high-population-density area, next to basic community services (i.e. fire stations, hospitals, airports, power stations, etc.) or close to occupied buildings.

Table 2 shows the indicators developed to assess the concerns of internal interested parties and the corresponding assessment scales.

3.3.2. DETERMINING INDICATORS FOR ASSESSING CONCERNS OF EXTERNAL INTERESTED PARTIES

As shown above, the interaction between construction projects and surrounding communities may modify the significance of environmental impacts. However, the significance of environmental impacts also depends on the concerns of external interested parties, which are mainly represented by the concerns and preferences of community associations, environmentalists, non-governmental organizations, the media, etc. Concerns amongst external parties are generally gathered in policy decisions made at the strategic level and expressed during the establishment of governmental policies, plans and objectives.

Over the last 30 years, strategic Environmental Action Programmes have guided the European Union in building a comprehensive legislative framework for environmental protection. The Sixth Environment Action Programme establishes the European framework for environment policy from 2002 to 2012, setting out four environmental priorities: (i) climate change, (ii) nature and biodiversity, (iii) health and the quality of life, and (iv) natural resources and waste.

Therefore, taking into consideration the international regulatory framework including current and emerging conditions, environmental impact AE-1 (generation of greenhouse gas emissions due to construction machinery and vehicle movements) should have exceptional significance.

Nature and biodiversity are also relevant to the Sixth Environment Action Programme, and therefore the concerns of interested parties should also include considerations derived from the direct influence of building construction projects on surrounding habitats and species. So as to assess the sensitivity of the natural environment in which a construction project is located, both the surrounding ecosystem's riches and the interaction between the construction project and its environment (and vice-versa) are considered.

The surrounding flora and fauna's degree of sensitivity to environmental impacts obviously differs from one place to the next. Biodiversity impacts derived from operations with vegetation removal (B-1), loss of edaphic soil (B-2), high potential soil erosion (B-3) and soil compaction (B-4) may have different consequences depending on the location of the construction project. All of these environmental impacts will be more significant if the geographical area affected by the construction project has some type of legal protection or is naturally unique. Otherwise, the significance of these environmental impacts depends on whether the affected area is located inside or outside the construction site perimeter. If the area affected by a construction project is located inside the construction site perimeter, it will be restored at the end of the construction work and therefore the significance of environmental impacts will be lower. However, if the affected area is located outside the construction site perimeter, it cannot be assumed that it will be restored, and the resulting environmental impacts may therefore have greater significance. The significance of environmental impact B-5 (interception of riverbeds, integration of riverbeds in the development, water channelling and stream water cutoff) will also vary according to the sensitivity of the local environment. The presence of natural riverbeds in legally protected areas or other areas that, due to their natural or archaeological uniqueness, etc., must be specially protected, will lead to greater significance.

The environmental impacts related to soil alteration SA-2 (use of concrete release agent at the construction site), SA-3 (use of cleaning agents or surface-treatment liquids at the construction site), SA-4 (dumping derived from the use and maintenance of construction machinery), SA-5 (dumping of water resulting from the execution of foundations and retaining walls), SA-6 (dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids) and SA-7 (dumping of sanitary water resulting from on-site sanitary conveniences) also depend on the sensitivity of the receiving environment. These environmental impacts should be found to be more significant in construction projects located in rural areas near water courses, areas with legal protection or other areas that, due to their unique nature, must be specially protected. The significance of these impacts should be regarded as lower in projects located in non-protected rural areas away from water courses and minor in projects located in urban areas, industrial parks and large waterproofed areas.

Some of the environmental impacts that are disturbing to people living near the construction site may also have a negative effect on the surrounding biodiversity. This is the case for the environmental impacts related to dust generation (L-1, L-2 and L-3) or noise generation (L-5). The significance of all these environmental impacts is greater in construction projects located in natural areas protected by law or other areas that, due to their special zoological interest, require special protection.

Environmental impacts related to incidents, accidents and potential emergency situations (AC-1, AC-2 and AC-3) may also have greater consequences in natural areas protected by law or other areas with high ecological and scenic value.

In order to integrate the interaction between construction activities and the environment in significance determinations, auxiliary means set up by the construction company must be taken into account. For the environmental impacts WE-1 (dumping of water resulting from the execution of foundations and retaining walls), WE-2 (dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids) and WE-3 (dumping of sanitary water resulting from on-site sanitary conveniences), direct dumping into the natural or urban environment must be penalized, and the significance should therefore be maximum. Connection to the sewage system, dumping in a septic tank and/or the existence of previous treatment should lower the final significance of environmental impacts related to water emissions. Finally, the existence of an in-situ waterproof settling basin or a watertight tank should lead to lower significance determinations.

Another environmental priority set up by the Sixth Environment Action Programme is health and quality of life. Therefore, the environmental impact AE-2 (emission of VOCs and CFCs) should be considered to have outstanding significance.

Natural resource conservation has been named as a priority issue by the current government. Environmental impact RC-1 (water consumption during the construction process) should be considered more significant if the water is taken from rivers or wells in drought-affected areas, and less significant if rainwater or tap water is used. Due to fuel scarcity, the significance of environmental impact RC-3 (fuel consumption during the construction process) should be considered high in all cases. For the same reason, the use of power generators as opposed to electricity from the grid should raise the significance of environmental impact RC-2 (electricity consumption during the construction process). The significance of environmental impact RC-4 (raw materials consumption during the construction process) will vary according to the recycled content in the raw materials.

Since we are linking significance judgements to European environmental priority areas, those environmental impacts related to waste generation also require further analysis.

The significance of environmental impacts WG-1 (generation of excavated waste material during earthworks), WG-2 (generation of municipal waste by on-site construction workers), WG-3 (generation of inert waste), WG-4 (generation of ordinary or non-special waste [wood, plastic, metal, paper, cardboard or glass]) and WG-5 (generation of special [potentially dangerous] waste) should be considered higher in projects lacking awareness of on-site waste management or which practice non-selective waste collection. The significance should be considered lower in projects that deliver waste to an authorized manager for future disposal or are unaware of the final waste destination. Finally, in-situ reuse or delivery to an authorized manager for future reuse or recycling should be assigned the lowest significance.

Table 2 shows the indicators developed to assess concerns of external interested parties and the corresponding assessment scales.

3.3.3. INDEPENDENCE TEST

In order to demonstrate that paired observations of the variables severity (SV) and concerns of interested parties (CO) are independent of one another, a series of χ^2 independence tests were conducted. A total of 76 new-start construction projects were analysed, representing a range of project sizes, types and settings such that the conclusions arising from this study are representative. Of these projects, 38 were for multi-family dwellings and they ranged from a small block of four dwellings with a total floor area of 216 m^2 to a property development including more than 100 dwellings and a total floor area of 12,681 m^2. The other 38 construction projects were for single-family houses and they ranged in floor area from 133 m^2 to 1,311 m^2 and had anywhere from one to four storeys.

Both the SV and the CO were calculated for each environmental impact in the 76 construction projects and corresponding χ^2 tests were performed with the help of Minitab. During the statistical analysis, construction projects for multi-family dwellings were distinguished from those for single-family houses since the environmental indicators for these two categories are replicated using different distributions [18].
Table 5 summarizes the results of the χ^2 test of independence. The p-value is higher than 0.05 in all cases, meaning that no relationship of dependence was identified between SV and CO.

ENVIRONMENTAL ASPECT	SINGLE-FAMILY HOUSES		MULTI-FAMILY DWELLINGS	
	χ^2	p-value	χ^2	p-value
AE-1	0.00	1.000	0	1.000
AE-2	0.00	1.000	0	1.000
WE-1	0.00	1.000	1.89	0.389
WE-2	6.02	0.198	1.31	0.860
WE-3	3.08	0.214	1.37	0.505
WG-1	4.28	0.640	0.90	0.924
WG-2	1.83	0.401	1.16	0.560
WG-3	7.21	0.125	1.24	0.872
WG-4	5.66	0.226	0.93	0.920
WG-5	0.83	0.662	0.67	0.715
SA-1	0.33	0.849	3.33	0.504
SA-2	0.00	1.000	0.00	1.000
SA-3	1.41	0.965	7.04	0.317
SA-4	2.66	0.616	1.59	0.810
SA-5	0.00	1.000	3.44	0.179
SA-6	2.06	0.725	8.49	0.075
SA-7	1.60	0.450	0.50	0.778
RC-1	3.26	0.515	4.81	0.307
RC-2	0.55	0.760	4.04	0.132
RC-3	0.00	1.000	0.00	1.000
RC-4	2.15	0.708	0.98	0.913
L-4	6.31	0.177	4.27	0.370
L-6	0.13	0.936	5.43	0.246
T-1	4.14	0.126	5.01	0.286
T-2	4.14	0.126	5.01	0.286
B-1	0.20	0.904	2.23	0.329
B-2	0.19	0.664	2.93	0.570
B-3	0.33	0.849	3.33	0.504
B-4	3.27	0.774	8.88	0.180
B-5	5.65	0.463	7.02	0.319
L-1	4.91	0.296	1.14	0.565
L-2	2.19	0.701	1.14	0.565
L-3	5.25	0.262	0.47	0.789
L-5	5.38	0.250	3.98	0.137
AC-1	6.39	0.172	1.08	0.898
AC-2	1.97	0.373	2.61	0.624
AC-3	1.22	0.874	1.08	0.898

Table 5. Results of the chi-square (χ^2) test of independence between the variables severity (SV) and concerns of interested parties (CO).

3.4. DETERMINING THE SIGNIFICANCE OF ENVIRONMENTAL IMPACTS

The significance of an environmental impact related to the construction process of a particular construction project was obtained using the following expression:

$$SG_{Ei} = SV_i \cdot CO_i \tag{1}$$

where SG_{Ei} denotes the significance of a particular environmental impact *i* of a specific construction project; SV_i denotes the impact severity, assumed to be 0 (non-existent), 1 (non-significant), 3 (marginally significant) or 5 (extremely significant); and CO_i corresponds to concerns of external and internal interested parties, assumed to be 1 (little/no concern to interested parties), 3 (secondary concern to all or most interested parties) or 5 (primary concern to all or most interested parties).

In cases where no information is available within the project documents to satisfactorily assess the potential environmental impacts, extremely significant severity and primary concern to all or most interested parties is automatically assumed (SV_i=5 and CO_i=5).

3.5. ESTABLISHING THE LEVEL OF ACCEPTABILITY OF A POTENTIAL ENVIRONMENTAL IMPACT

Establishing the acceptability of a potential environmental impact entails defining a threshold or quantitative criterion. In this case, if, after conducting the assessment, the significance of any environmental impact is found to be higher than 9, actions to eliminate or reduce that impact must be taken. These actions could include partially or completely abandoning the project, starting a re-design process, or providing a range of procedures for mitigating adverse environmental impacts that can then be implemented during on-site construction activities as well as corresponding operational controls so as to reduce the significance of the environmental impacts to a level that is acceptable to the interested parties.

Fig. 2 summarizes the methodology for predicting and assessing environmental impacts related to the construction of residential buildings and the corresponding established levels of acceptability.

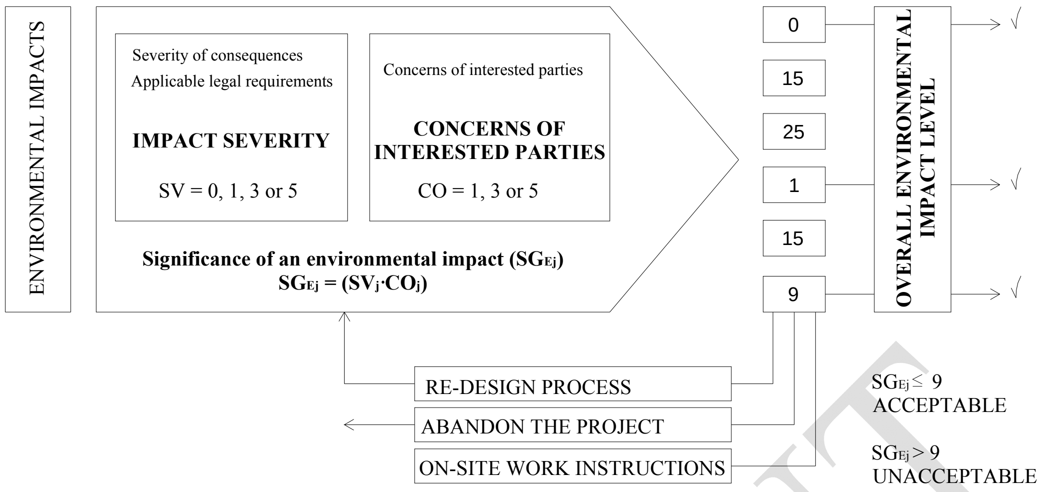

Figure 2. Overview of a particular construction project assessment.
Source: drawn up by the authors.

3.6. DETERMINING THE OVERALL ENVIRONMENTAL IMPACT LEVEL OF A CONSTRUCTION PROJECT

This methodology assesses the overall environmental impact level of a construction project as shown in (2):

$$R_E = \sum_{i=1}^{n} SG_{Ei} \qquad (2)$$

where R_E is the overall environmental impact level of a construction project and SG_{Ei} is the significance of a particular environmental impact *i* in a specific construction project.

The construction project with the highest sum is considered to have the most significant environmental impact (Fig. 2).

4. CASE STUDIES

To demonstrate the benefits of the improved methodology, this section applies the research undertaken to the construction projects P03 and P05 described in Gangolells et al. [18]. This section aims to demonstrate how the assessment of the concerns of internal and external interested parties actually influences the significance of environmental impacts.

Construction project P03 consists of one six-storey building containing 31 dwellings and a two-storey underground car park. It is located in a city centre close to an old cathedral. Because it is on a busy street, all provisional on-site facilities and storage areas are placed inside the construction site perimeter. Although the perimeter itself takes up 1.5 m of the public sidewalk, the free space left for foot traffic is over 1.00 m wide. Neither the number of available parking places nor the space for vehicle circulation are affected by the construction site. Since construction project P03 is located in an urban area, the existing water supply, electrical grid and sewage system are available during the construction project. The construction project's documents do not provide information about the recycled content of the raw materials. However, the documents do plan for selective waste collection and later delivery to an authorized manager for future reuse or recycling (whenever possible). Further details on the main P03 construction characteristics are described in Gangolells et al. [18].

Construction project P05 is the first building to be erected in a new development area. The construction project contains eight dwellings in five storeys and one underground car park. Located in a non-protected rural area near a low-traffic-density road, the nearest neighbouring town centre is 1.8 km away. The construction site is surrounded by other buildable lots, a forested area (150 m) and a natural riverbed (200 m). Infrastructure development is not yet finished and therefore neither water nor electricity networks are available. For this reason, on-site electricity will be supplied by a power generator and the water needed during the construction project will be taken from the river. Because no sewage system is available yet, the construction project documents call for watertight septic tanks. Provisional on-site facilities are located in the adjoining buildable lot, which, after earthworks, has neither vegetation nor edaphic soil. The construction project documents call for 40% recycled content in the raw building materials but make no provisions regarding on-site waste management. Construction project P05 is further described in Gangolells et al. [18].

Appendix A shows detailed assessment results for construction projects P03 and P05.

5. DISCUSSION OF RESULTS

Construction project P03 had the higher overall environmental impact level (106) when the calculations only took into account the severity of the environmental impacts [18], whereas project P05 had a score of 100 [18]. When the concerns of interested parties were included in the assessment, project P05 obtained the higher overall environmental impact level (338), whereas P03 scored 308. The construction of project P05 involved a higher overall environmental impact level because it is located in a non-protected rural area with no available infrastructure. Moreover, its construction project documents did not provide for selective waste collection followed by delivery to an authorized manager.

After considering concerns of interested parties, 12 environmental impacts related to the erection of construction project P03 were found to be highly significant. Some of these (AE-1, RC-3, L-4, T-1 and AC-1) were previously deemed highly significant in Gangolells et al. [18]. However, some other environmental impacts were found to be highly significant after taking into consideration the concerns of interested parties. This is the case for environmental impact AE-2 (emission of VOCs and CFCs), which is framed within one of the four environmental priorities established by the Sixth Environment Action Programme. The improved methodology also highlights the significance of environmental impact RC-4 (raw materials consumption during the construction process) for construction project P03 because, although its severity is considered to be marginally significant, the documents of the construction project do not specify the use of recycled-content materials. In the presence of neighbouring communities, the improved methodology highlights the significance of environmental impacts L-1 (dust generation in activities with construction machinery and transport), L-2 (dust generation in earthworks activities and stockpiles), L-5 (generation of noise and vibrations due to site activities), AC-2 (breakage of underground pipes) and AC-3 (breakage of receptacles with harmful substances). In contrast, some environmental impacts decreased in significance when the concerns of interested parties were taken into account. Construction project P03 calls for selective waste collection followed by delivery to an authorized manager for future reuse or recycling and, because of this, environmental impacts WG-3 (generation of inert waste), WG-4 (generation of ordinary waste) and WG-5 (generation of special [potentially dangerous] waste) were considered to be acceptable and therefore no extra on-site instructions were required. The severity of environmental impacts RC-1 (water consumption during the construction process) and RC-2 (electricity consumption during the construction process) was found to be extremely significant, however, and because water and electricity networks are available for construction project P03, the significance of these impacts remains at 5.

Using the improved methodology to assess construction project P05 allowed the identification of 13 highly significant environmental impacts, as opposed to the four identified in Gangolells et al. [18]. Environmental impacts SA-3 (use of cleaning agents of surface-treatment liquids at the construction site), SA-5 (dumping of water resulting from the execution of foundations and retaining walls) and L-3 (dust generation in cutting operations) were already identified as highly significant, but the decision to assess the concerns of external interested parties also raised the significance of other environmental impacts such as AE-1 (generation of greenhouse gas emissions due to construction machinery and vehicle movements), WG-1 (generation of excavated waste material during earthworks), WG-3 (generation of inert waste), WG-4 (generation of ordinary or non-special waste), WG-5 (generation of special [potentially dangerous] waste), SA-2 (use of concrete release agent at the construction site), SA-4 (dumping derived from the use and maintenance of construction machinery), SA-6 (dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids), RC-2 (electricity consumption during the construction process) and RC-3 (fuel consumption during the construction process). Addressing the concerns of interested parties decreased the initial estimation of the significance of the environmental impact WE-1 (dumping of water resulting from the execution of foundations and retaining walls) because the construction project documents for P05 called for the use of a watertight tank.

6. CONCLUSIONS

This study is a step forward in the current efforts to improve the determination of environmental impact significance in the development and implementation of environmental management systems in construction companies. Gangolells et al. [18] presented a methodology in which objective judgements were used transparently to determine the severity of environmental impacts. Because the ISO 14001:2004 [8] and

ISO 14004:2004 [19] standards highlight the need to better understand how the concerns of interested parties actually modify the significance of an environmental impact, current research has added this extra criterion to the existing assessment framework. The concerns of internal and external interested parties are thus brought into the assessment process, thereby making the significance determination more realistic and adapted to the inherent peculiarities of the construction sector.

The strength of this methodology lies in the fact that the significance determination method is adjusted to both local perceptions and international challenges, which ensures that the outcome of the assessment of environmental impacts is appropriate to social, ecological, legal and political settings. For example, an environmental impact with a marginally significant severity that is of primary concern to all or most interested parties is rated as having the same significance as an environmental impact with an extremely significant severity that is of secondary concern to all or most interested parties.

Because the success of an environmental management system largely depends on the correct identification and assessment of environmental impacts, the main contribution of this methodology is to support the implementation of environmental management systems in construction companies by providing guidance for contractors undertaking ISO 14001:2004 certification [8]. However, the methodology can also be a powerful assessment tool for helping construction companies to improve their on-site environmental performance. Firstly, the methodology is able to provide a comprehensive overview of the environmental on-site performance of a construction project during the pre-construction stage (in the design, planning and preparation stages). A zero on the overall environmental impact level of a construction project would be the best performance in those environmental areas deemed significant. Higher scores would indicate a construction project conforming to typical standards and practices in the region. Significantly higher scores would indicate performances that are worse than typical. Secondly, the methodology is able to rank the significance of the various environmental impacts of each assessed project, so it can be used to compare the score for one environmental impact with those of other impacts within the same construction project. Significant environmental impacts are determined in advance (i.e. prior to the construction stage). Therefore, it is possible to take actions aimed at eliminating those impacts completely (so that there is no potential of negatively affecting interested parties) or partially (so that the impacts are reduced to a level that is acceptable to the interested parties). Finally, the assessment results also make it possible to compare the absolute significance of a particular environmental aspect across several projects.

Further research needs to be done within the framework of the environmental management system in order to ensure continual improvement in construction sites. When significant environmental impacts can be identified in advance, corresponding on-site measures can be implemented. The extent to which applicable requirements are being met can be determined by conducting on-site performance monitoring and measurement. However, this would require the definition and acquisition of real performance data related to each identified significant environmental impact.

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APPENDICES

Appendix A. Assessment results for construction projects P03 and P05.

ENVIRONMENTAL ASPECT		P03				P05			
		SV[1]	CO[2]	SG_E[3]		SV[1]	CO[2]	SG_E[3]	
AE-1	Generation of greenhouse gas emissions due to construction machinery and vehicle movements.	5	5	25	=	3	5	15	+
AE-2	Emission of VOCs and CFCs.	3	5	15	+	1	5	5	=
WE-1	Dumping of water resulting from the execution of foundations and retaining walls.	1	3	3	=	5	1	5	-
WE-2	Dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids.	1	3	3	=	3	1	3	=
WE-3	Dumping of sanitary water resulting from on-site sanitary conveniences.	1	1	1	=	1	3	3	=
WG-1	Generation of excavated waste material during earthworks.	3	1	3	=	3	5	15	+
WG-2	Generation of municipal waste by on-site construction workers.	3	1	3	=	1	5	5	=
WG-3	Generation of inert waste.	5	1	5	-	3	5	15	+
WG-4	Generation of ordinary or non-special waste (wood, plastic, metal, paper, cardboard or glass).	5	1	5	-	3	5	15	+
WG-5	Generation of special (potentially dangerous) waste.	5	1	5	-	3	5	15	+
SA-1	Land occupancy by the building, provisional on-site facilities and storage areas.	3	3	9	=	3	1	3	=
SA-2	Use of concrete release agent at the construction site.	3	1	3	=	3	5	15	+
SA-3	Use of cleaning agents or surface-treatment liquids at the construction site.	0	1	0	=	5	5	25	=
		1	1	1	=	1	5	5	=
SA-4	Dumping derived from the use and maintenance of construction machinery.	3	1	3	=	3	5	15	+
SA-5	Dumping of water resulting from the execution of foundations and retaining walls.	1	1	1	=	5	5	25	=
SA-6	Dumping of water resulting from the process of cleaning concrete chutes or dumping of other basic fluids.	1	1	1	=	3	5	15	+
SA-7	Dumping of sanitary water resulting from on-site sanitary conveniences.	3	1	3	=	1	5	5	=
RC-1	Water consumption during the construction process.	5	1	5	-	3	3	9	=
RC-2	Electricity consumption during the	5	1	5	-	3	5	15	+

ENVIRONMENTAL ASPECT		P03				P05			
		SV[1]	CO[2]	SG_E[3]		SV[1]	CO[2]	SG_E[3]	
	construction process.								
RC-3	Fuel consumption during the construction process.	5	5	25	=	3	5	15	+
RC-4	Raw materials consumption during the construction process.	3	5	15	+	3	3	9	=
L-1	Dust generation in activities with construction machinery and transport.	3	5	15	+	3	3	9	=
L-2	Dust generation in earthworks activities and stockpiles.	3	5	15	+	3	3	9	=
L-3	Dust generation in activities with cutting operations.	0 1	5 5	0 5	= =	5 1	3 3	15 3	= =
L-4	Operations that cause dirtiness at the construction site entrances.	5	5	25	=	3	1	3	=
L-5	Generation of noise and vibrations due to site activities.	3	5	15	+	1	5	5	=
L-6	Landscape alteration due to the presence of singular elements (cranes).	1	5	5	=	1	3	3	=
T-1	Increase in external road traffic due to construction site transport.	5	5	25	=	3	1	3	=
T-2	Interference in external road traffic due to the construction site.	0	5	0	=	0	1	0	=
B-1	Operations with vegetation removal (site preparation).	3	1	3	=	3	1	3	=
B-2	Operations with loss of edaphic soil (site preparation).	3	1	3	=	3	1	3	=
B-3	Operations with high potential soil erosion (unprotected soils as a consequence of earthworks).	3	1	3	=	3	3	9	=
B-4	Opening construction site entrances with soil compaction.	0	1	0	=	0	3	0	=
B-5	Interception of riverbeds, integration of riverbeds in the development, water channelling and stream water cutoff.	0	1	0	=	0	3	0	=
AC-1	Fires at areas for storing flammable and combustible substances.	5	5	25	=	3	3	9	=
AC-2	Breakage of underground pipes (electric power cables, telephone lines, water pipes, or liquid or gaseous hydrocarbon pipes).	3	5	15	+	3	3	9	=
AC-3	Breakage of receptacles with harmful substances. Storage tanks for dangerous products.	3	5	15	+	3	1	3	=
OVERALL ENVIRONMENTAL IMPACT LEVEL		106[4]		308[5]		100[6]		338[7]	

[1] Severity of the environmental impact. Values taken from Gangolells et al. [18].
[2] Concerns of interested parties.
[3] Significance of the environmental impact. Environmental impacts whose significance levels have increased (+), decreased (-) or remained steady (=) when concerns of interested parties are considered.
[4] Overall environmental impact level of the construction project P03 without considering concerns of interested parties [18].

[5] Overall environmental impact level of the construction project P03 considering concerns of interested parties.
[6] Overall environmental impact level of the construction project P05 without considering concerns of interested parties [18].
[7] Overall environmental impact level of the construction project P05 considering concerns of interested parties.

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