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Assessing the environmental impacts of construction in Antarctica

Dielly Christine Guedes Montarroyos[a,*], Cristina Engel de Alvarez[b], Luís Bragança[c]

[a] Department of Civil Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal
[b] Laboratório de Planejamento e Projetos, UFES, Av. Fernando Ferrari, 514, Room 7, Vitória, Espírito Santo 29075-910, Brazil
[c] Department of Civil Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal

1. Introduction

The origin of the Environmental Impact Assessment (EIA) was in 1969, as part of the US National Environmental Policy Act which imposed the obligation of all federal agencies to evaluate the potential impacts of activities on the environment (Ortolano and Shepherd, 1995). Its emergence coincided with the recognition of the fact that human activities could lead to changes in the natural setting (Morgan, 2012).

The EIA is a procedure to identify, predict, investigate, evaluate and mitigate impacts from activities that are likely to have substantial effects on the environment. The evaluation must happen during the design and planning phase and can be done in different approaches such as interaction matrices, prediction of impacts, investigation and decision-making by government agencies (Toro et al., 2013).

Recognized and used by many countries, the EIA methods are based on systematic environmental studies, in addition to relying on the support of a public consultation to assess project execution (Jay et al., 2007). The EIA have contributed to monitoring the development of environmental protection projects, the implementation of environmental laws and mainly as an instrument that assists decision-making in several administrative spheres (Morgan, 2012).

Likewise, the EIA method involves public consultation, debates and decision-making in Antarctica. The methods rely on international collaboration in Antarctica since the issues can affect a global common (Bastmeijer and Roura, 2008).

It is known that Antarctica is the most inhospitable, the most remote and the most unpopulated place on earth. Antarctica is also an environmentally vulnerable land (Tin et al., 2009) and it is highly valued for the importance of its scientific research whose results have worldwide implications (Hughes et al., 2011), like the research on climate changes and on pharmacological discoveries (Dodds et al., 2017).

It is worth remembering that any change or environmental impact on Antarctica may have catastrophic consequences, and most of the Antarctic research depends on the continuous human presence on the continent and on the obedience to the strict environmental legislation: the Protocol on Environmental Protection to the Antarctic Treaty (Montarroyos et al., 2018).

Because of the sovereignty territorial disputes that had occurred in Antarctica in 1959, twelve countries signed the Antarctic Treaty that recognized the continent as a place for scientific and peaceful purposes for 30 years (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b). Thirty years later, the discussion of the signatory parties became mainly environmental, motivating the preparation of the Protocol on Environmental Protection to the Antarctic Treaty in 1991. The Protocol recognized, among other relevant matters, the prohibition of mineral resource activities, ensuring the peaceful purposes and the strict environmental protection. It also determined that the parties would prepare annual reports to the Antarctic Treaty Consultative Meeting (ATCM), as a way to update and implement the Protocol contents (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b).

One of the main issues addressed by the Protocol was the improvement of the methods to evaluate environmental impacts. The legislation imposed requirements for all planned activities on the continent as a way to preserve the environment (Hemmings and Kriwoken, 2010). Before the execution of any activities in Antarctica –construction of new scientific stations or scientific research development – the Protocol established that all nations should identify of the level of environmental impact the activity as having: less than a minor or transitory impact; minor or transitory impact; or more than a minor or transitory impact (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b). The recognition of the impact levels of activities provided specific guidance on the preparation and controlling of the EIAs (Bastmeijer and Roura, 2008).

The Preliminary Assessment (PA) is desirable, but not mandatory. With no procedures defined by Protocol, this type of evaluation focuses on initial discussion about potential impacts with less intensity and duration (Tarasenko, 2009). On the other hand, depending on the level of impact, the Initial Environmental Evaluation (IEE) and Comprehensive Environmental Evaluation (CEE) shall be mandatory according to the Annex 1 of the Protocol. The annex provides guidelines and the minimum requirements to prepare and deliver EIA reports (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b).

* Corresponding author at: Av. Fernando Ferrari, 514, Room 7, Goiabeiras, Vitória, Espírito Santo 29075-910, Brazil.
E-mail addresses: id6667@alunos.uminho.pt, dielly.christine@faesa.br (D.C.G. Montarroyos), cristina.engel@ufes.br (C.E. de Alvarez), braganca@civil.uminho.pt (L. Bragança).

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1.1. Initial Environmental Evaluation (IEE) and Comprehensive Environmental Evaluation (CEE)

In accordance with Article 2, the IEE is a method that shall be prepared in order to help nations perform an activity. With regards to the minimum requisites to prepare IEE, the Protocol defines the inclusion of descriptive data including purpose, location, duration, intensity, as well as consideration of probable and cumulative impacts. Similarly, the CEE is required in order to start the proposed activities in Antarctica. Besides being mandatory, this type of EIA must be made publicly available for comments and must be forwarded to the Committee for Environmental Protection (CEP). The Committee has to review CEE and decide on their prohibitions or proceedings (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b).

In addition to the information required in the IEE, the preparation of the CEE draft shall include: description of the proposed activity, descriptive information about the initial environmental condition; descriptive methods to forecast the impacts; estimation of the nature, extent, duration, intensity of the impact; identification of the indirect, cumulative or unavoidable impacts; consideration of the effects of the proposed activities; identification of gaps and uncertainties about the conduction of the activities; and identification of measures to minimize or mitigate impacts (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b). Because it involves more than minor or transitory impacts, the CEE is a process to accurately evaluate activity impact, therefore it also involves public consultation and participation of the committee to review the drafts (Bastmeijer and Roura, 2008).

The CEE procedures are established according to the following steps: 1) preparation and public availability of the CEE draft; 2) evaluation of the draft by the committee in the annual Antarctic Treaty Consultative Meeting; and 3) presentation of the final version considering all revisions and comments. No activity can be undertaken, or no final decision shall be procced, without the previous analysis of the draft by the committee. The final CEE shall be made publicly available to all nations for consideration (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b). Thus, the process is characterized by a high level of transparency and international collaboration. According to Hemmings and Kriwoken (2010) these steps represent an efficient quality control to evaluate environmental impacts.

However, even though the EIA process is an example of international collaboration, it presents limitations. One of them is the lack of interest among nations in the EIA development. Even when an activity is classified as having more than a minor or transitory impact, i.e., events that may alter significantly the environment, there is a low percentage of CEE developed for Antarctic activities (Secretariat Of Antarctica Treaty (SAT), 2017), and less than half of the Antarctic Treaty parties make the CEE publicly available (Hemmings and Kriwoken, 2010; Secretariat Of Antarctica Treaty (SAT), 2017).

With respect to construction activities, they were occasionally evaluated as having a minor or transitory impact and then conducted to IEE procedures. As the interpretation of the impact levels is undefined and can vary, it may cause an incorrect evaluation and assessment of environmental impacts (Tarasenko, 2009).

Moreover, the EIAs report raised possible doubts about the process and stimulated systematic analysis of the published drafts emphasizing the importance of these analyses for the adoption of measures to mitigate the impacts and preserve the environment (Antarctic Treaty Consultative Meeting (ATCM), 2016a, 2016b).Thus, the absence of the EIA in public domain or submission of reports incompatible with the proposed activities may compromise the protection of the Antarctic environment, and can raise doubts about the efficiency of the EIA procedures established by the Protocol.

Aware of these limitations, the CEP anticipated the need for an enhancement of EIA proceedings in Antarctica. Thus, the final report of the Thirty-ninth Antarctic Treaty Consultative Meeting in 2016 recommended the following: 1) a reduction of the time limit for analysis and response of the CEE as a way to promote commitment of the consultative parties; 2) a description of methods to distinguish activities impacts; 3) and an increase of the minimum requisites for IEE preparation, making the impact analyses obligatory according to the requisites mentioned above. Furthermore, the CEE shall include an evaluation of the nature, extent, duration, intensity of the impacts and the unavoidable impacts. Such issues, among other criteria, can raise an alert for the interference of activities in every area, especially in the area of environmental protection. These issues can also help the process of evaluation by making possible the standardization and the exchange of international information, while meeting the main principles of the Protocol (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b).

The ATCM decided that the CEE should include the following demands: description of the proposed activity, initial environmental reference state and method to forecast impacts; estimation of the nature, extent, duration and intensity of the proposed activity impacts; identification of the probability of the occurrence of unavoidable, cumulative, indirect or second order impacts (Antarctic Treaty Consultative Meeting (ATCM), 2005). The identification of the environmental impacts involves the recognition that an activity is able to change the environment state.

In summary, according the Annex I and amendments to the Protocol, an impact may be identified by the requisites mentioned, as shown in the Table 1 (Antarctic Treaty Consultative Meeting (ATCM), 2016a, 2016b).

Due to the transparency of the process, most countries have presented environmental impact evaluations in tables called “impact matrix”, that summarize the obligatory results.

Similar to the Protocol and annexes, the Sustainable Building Tool – SBTool (Larsson, 2015) has been assessing environmental issues according to the requirements for the construction of buildings in urban areas around the world. The SBTool, as a main global tool, aims at promoting building evaluations without compromising the scientific accuracy of the environmental assessments.

1.2. Sustainable building tool

Managed by International Initiative for Sustainable Built Environment (iiSBE), an international non-profit organization, the SBTool is considered the most comprehensive (Shan and Hwang, 2018), flexible, adaptable and sustainable assessment tool (Alyami and RezguI, 2012). For years the SBTool has been the only tool developed to be adapted to other locations (Andrade and Bragança, 2016), allowing users to adjust the indicators according to local priorities (Bragança and

Table 1
Definitions and parameters of the requisites to evaluate environmental impacts. The example used is snow/ice contamination. Source: Polar Research Institute of China (2014).

Requisites	Definition	Parameter example
Nature	Type of the of the impact caused by the activities	Contamination of snow/ice
Duration	Duration of possible impacts on the environment	Years
Extent	The detectable geographical area or volume of changes that may occur	Local
Intensity	Estimative of the intensity of the impact on the natural function	Low
Probability	Likelihood of impact occurring	Certain

Table 2
Scorecard and weighting factors of SBTool. Souce: Larsson (2015).

Adjustable	Pre-defined values			
Local effect (El) 1 to 5 points	Extent of potential effect (Ep) 1 to 5 points	Duration of potential effect (Ed) 1 to 5 points	Intensity of potential effect (Ei) 1 to 3 points	Primary system directly affected (Es) 1 to 5 points
(1) Much less (2) Less (3) Ok (4) More (5) Much more	(1) Building (2) Site/Project (3) Neighborhood (4) Urban/ Region (5) Global	(1) 1 to 3 years (2) 3 to 10 years (3) 10 to 30 years (4) 30 to 75 years (5) > 75 years	(1) Minor (2) Moderate (3) Major	(1) Functionality/ serviceability (1) Cost e economics (2) Well-being, security and productivity of individuals (2) Social and cultural issues (3) Land resources (3) Non-renewable material resources (3) Non-renewable water resources (4) Non-renewable energy resources (3) Ecosystem(s) (4) Local and regional atmosphere (5) Global climate

Mateus, 2017).

From 2007 on, in the updated version, a quasi-objective method to distinguish the weighting elements between loads and effects of the construction on the environment or humans was defined. The weighting system was defined according to the requisites of Local effects (El); Extent of potential effect (Ep); Duration of potential effect (Ed); Intensity of potential effect (Ei); and Primary system directly affected (Es). The weighting system presented by the SBTool has the objective of quantifying the indicators or criteria for evaluating the sustainability of buildings (Larsson, 2015; Bragança and Mateus, 2017).

Therefore, the SBTool assigns reference values to the parameters, ranging from 1 to 5 (Table 2) (Larsson, 2015). The weight assignment of the values in the indicated scale (1 to 5 points) shows the significance of the effect or indicator according to the requisites, which implies that a higher number means a more significant effect.

In the SBTool, in the columns about Extent (Ep), Duration (Ed) and Intensity (Ei) of potential effect there are predefined values that cannot be modified by users. Only the Local effect (El) column is adjustable according to the local specificity. The column Primary system (Es) has the parameter and values established by international normative (Larsson, 2015).

Based on the wide range of sustainable and environmental issues that the SBTool can measure, and the possibility to use it in different locations to perform accurate assessment according to local priorities, it was identified that the SBTool scorecard system has potential for being used in Antarctica.

Aware that the scale numbers and parameters may not be representative of the environmental evaluation on the continent, so adaptation of the SBTool is required in order to be used in the Antarctic region.

Understanding that EIA can provide data to comprehend impacts that may occur on the continent (Tarasenko, 2009), and the adaptation of SBTool scorecard and weighting system specific for the continent can support the improvement of the EIA process, the present research aimed to investigate the environmental impacts related to construction activities in Antarctica. The purpose is developing an assessment method based on the SBTool to analyze and verify environmental impacts.

The EIA data, Consultative Meeting reports, the Protocol and annexes supported the method aiming to allow an environmental assessment in consonance with the Antarctica current legislation.

2. Methodology

To meet our research objectives: to assess, analyze and verify environmental impacts related to construction activities in Antarctica, the research was organized according to the following steps:1) inquiry and analysis of guidelines that regulate the procedures related to environmental impact assessments; 2) investigation of all EIA reports publicly available from 2006 to 2018 on the ATCM website for construction activities; 3) analysis of the process to validate EIA reports for the construction of scientific stations; 4) identification of the CEE requisites for new constructions in Antarctica; 5) proposal of an assessment method and based on SBTool generic scorecard.

2.1. Guidelines for environmental impact assessments

In the first step of the research methodology documents and legislation to conduct activities in Antarctica were collected: Antarctic Treaty; Environment Protocol; Annex 1; Rules of Procedure of the Committee for Environmental Protection; Guidelines for EIA in Antarctica; and ATCM Rules of Procedure (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b). These documents – publicly available on the Secretariat of the Antarctic Treaty website – guide the activities and establish procedures to plan and implement projects on the continent.

Thus, the research initially involved analysis of the Environmental Protocol as the main document to support environmental control in Antarctica – including annexes and updated articles. In all these documents the EIA procedures were inspected.

In addition, the inquiry involved reports of the ATCM and resolutions that might influence the preparation of the EIA reports. The selected documents were: the final reports from 1961 to 2017 of the ATCM; and ATCM resolutions whose category was defined as “Comprehensive environmental evaluation”, “Environmental protection” or “CEP strategy”.

The data were organized according to the year of publication for chronological understanding. The main keywords that guided the search in all files were “Environmental Impact”, “EIA”, “Comprehensive environmental evaluation”, and “Initial Environmental Evaluation”. The appreciation of these documents made possible the delimitation of the research, the analysis of the environmental assessment process in Antarctica, the examination of the publicly available data and the comparison between the procedures recommended by the Antarctic Treaty Consultative Party (ATCP) and the procedures performed by the nations.

2.2. EIA reports for construction activities in Antarctica

Searching for transparency in the EIA process, drafts, documents and reports prepared by the nations shall be made publicly available. Therefore, on the website of the Secretariat of the Antarctic Treaty (SAT), in the section of the Environmental Protocol and EIA subsection, the EIA database for activities on the continent can be found. The database was classified according to the assessment type – IEE or CEE –, year of publication, party or nation, and topic, which can be

categorized as construction, science, drilling, tourism among other activities (Secretariat of Antarctica Treaty (SAT), 2016a, 2016b).

In this step, all types of EIA data that have addressed the topic "construction/ operation of facilities", published by all nations, from 2006 until today, have been collected. The year 2006 was decided based on the guidelines updated in the Consultative Meeting in 2005, which established impact identification and evaluation.

The reason for this data gathering was to analyze, in a measurable manner, the development of the CEE and IEE reports for construction, as well as identifying how many and what kind of activities performed in Antarctica required the preparation of EIA reports.

2.3. EIA reports for construction and operation of scientific stations

In order to verify whether all scientific stations built in Antarctica have had the EIA made accessible in the public domain, a review was carried out in the Antarctic Station Catalogue of the Council of Managers of National Antarctic Programs (Council of Managers of National Antarctic Programs (COMNAP), 2017). The catalogue presents 76 scientific stations, however six scientific stations are included in this study whose date of construction, renovation or expansion was after 2006.

Besides the analysis of the EIA documents along with the catalogue review, the final reports of the ATCM from 2006 to 2017 were examined. In these reports, it was verified if one of the selected scientific station was mentioned in the meeting, if any consultative parties expressed concern about the impact of the construction of a scientific station, as well as if parties revised the EIA reports. To this end, the names of the six selected scientific stations along with the names of their countries, and the keywords "CEE", "IEE", "Scientific station", "building" and "construction activities" were searched in all of the 21 ATCM files. The data gathered were organized according to the name of the scientific station followed by the year of publication.

These meeting reports contributed to understanding the validation process of EIA and to identifying gaps and potentialities for the development of the environmental assessment in Antarctica. Additionally, the research content included the analysis of debates about CEE.

2.4. Comprehensive environmental evaluation for construction of scientific stations

The step involves the exploration of the environmental impacts that may occur according to the drafts and final version of the EIA for buildings, and investigation and discussion about the parameters used by nations that may contribute to the data standardization, especially for the preparation of the weighting factor table for Antarctica.

To obtain the parameters according to the requisites of extent, duration, intensity and probability, the content of the CEE reports of the six selected scientific stations were analyzed. The investigation was focused specifically on the table of the Impact Matrix (Table 2) which contains the environment impact and metrics for the construction activities.

In addition, it can be highlighted that the SBTool does not include the requisite or factor of probability. However, this requisite is widely used in EIA around the world, and is required by the Protocol. Thus, in accordance with the Antarctica legislation and international practices, probability of potential effect was taken into consideration for this assessment and exploratory process.

The drafts and final CEEs were examined and the metrics of each nation for the requisites/factors were summarized and organized in the table adapted from SBTool. The values of the parameters in the table were organized in a numerical scale from 1 to 5 points, which 1 represents the lowest level of requisite significance and 5 the highest level of requisite significance. This step allows for comparative analysis of the results and supporting the preparation of the weighting table of SBTool Antarctica.

2.5. Weighting system, proposal of an assessment method and discussions about the results

Based on the information obtained from the previous steps, this step involved the quantification of the data to support the environmental impact factor and weighting analyses of the construction activities on the continent.

Firstly, the parameter values from 1 to 5 obtained from the drafts and final versions of CEEs for each requisite of Extent (Ep), Duration (Ed), Intensity (Ei) and Probability (Pe) were inserted in a comparative table and they were connected to a scale of 5 colors which represents: green (1), yellow (2), orange (3), dark orange (4)and red (5). The method aims at highlighting the most significant impact and requisites, in which green represents lower significance and red highest significance. The absence of color means that the evaluation of an effect requisite was not done by the nation.

Subsequently, a quantitative evaluation was done. The impact factor algorithm[1] (Fk) is obtained by the multiplication of the factor values contained in the assessment tool: Local effects (El); Extent of potential effect (Ep); Duration of potential effect (Ed); Intensity of potential effect (Ei); and Primary system directly affected (Es).

$$Fk^1 = \text{El x Ep x Ed x Ei x Es} \quad (1)$$

Since the EIA in Antarctica included the factor of Probability (Pe), to obtain the Fk specifically for Antarctica, an adaptation of the SBTool algorithm[1] was made by adding the Pe factor (2). In the same way as the others factors, the parameter values of Pe were defined based on the previous methodological step, from the CEE analysis.

$$Fk = \text{El x Ep x Ed x Ei x Es x Pe} \quad (2)$$

From the Impact Factor (Fk) of each nation, the Weight (W) was obtained. To reach the percentage that represents the impact on the continent, the sum of the Fk was done according to the algorithm 3:

$$W = \frac{Fk}{\sum_{k=1}^{n} FK} \quad (3)$$

The values of Fk and W were organized in a comparative table of CEEs responses. The table contains the values of each proponent nation and the values of the Primary system directly affected (Es).

According to the SBTool and following the requirements of the Protocol, the Primary systems directly affected (Es) are: local and regional atmosphere; land or ice; environmental values; ecosystem; and water resources. Given the lack of standardizing procedures for buildings in the environmental impact assessment, the impacts related to the Primary system (Es) were combined and had their weights added. This combination has allowed the systematization of the data presented, interpretation of the significance of each Es and definition of the Es reference values.

From these results, it was possible to identify weight values of all requisites/factors and adapt of the SBTool weighting system for the Antarctic context, fostering EIA for buildings with regard to procedural accuracy of an area of environmental and scientific interest.

3. Results and discussion

3.1. EIA reports for construction activities in Antarctica

IEE reports presented higher numbers than the CEE reports (Fig. 1). From 2006 to 2017, 79 IEE reports for activities related to construction such as modernization, refurbishment, facilities maintenance, logistic, installation of turbines, shelters and summer stations were published (Secretariat Of Antarctica Treaty (SAT), 2017), while the CEE published only 17 documents.

The activities evaluated by IEE, though classified as of minor or transitory impact, can cause harm to the local ecosystem, for example disposal of waste, ground/ice pollution, among other irreversible

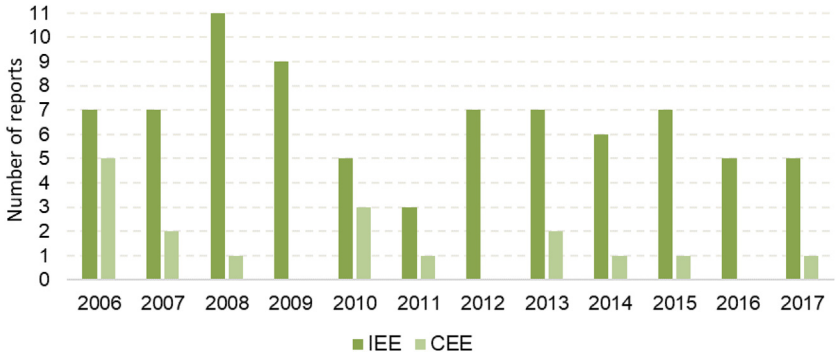

Fig. 1. Number of IEE and CEE reports for construction-related activities from 2006 to 2017 from Secretariat Of Antarctica Treaty (SAT) (2017).

impacts. In a specific analysis of the IEE reports from January 2006 to December 2017, it was observed that from the 79 IEE reports 29 were focused on activities that involved construction of temporary rooms, installation of antennas, wind turbine, among other facilities; 27 were related to construction, maintenance or refurbishment of scientific stations; 11 were about construction of fuel tanks; 8 were related to construction of shelters or emergency modules; and 4 were about construction of paths.

This investigation shows a high number of IEE reports related to construction, maintenance, refurbishment and disassembly of scientific stations.

Although there is no predefined condition on which construction activities should be forwarded to the IEE or CEE reports, it was noticed that most CEE reports were related to planning and execution of large-sized scientific station projects. From the 17 evaluated reports, 11 were about construction of scientific stations, while the other activities referred to the fuel tank installation, construction of two airplane runways, and three exploration and science proceedings.

3.2. EIA reports for construction and operation of scientific stations

The second investigation considered the analysis of CEE and IEE reports specific to the construction of scientific stations. This research refinement emphasizes difficulties and opportunities concerning the validation procedures of the reports.

Table 3 presents the systematization of EIA published data, COMNAP catalogue and the content of ATCM, which it was possible to observe: a) reduced time spent in analysis of reports by the committee; b) increase of the number of report reviews after 2006; c) absence of data reports related to expansion or renovation of buildings.

Formulated from Council of Managers of National Antarctic Programs (COMNAP) (2017), Secretariat Of Antarctica Treaty (SAT) (2017), National Academy of Sciences of Belarus (2015), Polar Research Institute of China (2014), Korea Polar Research Institute (2011), National Centre for Antarctic and Ocean Research (2010), British Antarctic Survey (2007) and Belgian Science Policy (2006).

Hemmings and Kriwoken (2010) highlighted the limitations of the process of elaborating and submitting CEE reports. Among other issues, they emphasized the lack of commitment to the reports, characterized by the absence of revisions between the draft phase and the final proposal. Until 2009, none of the draft reports submitted and revised by the ATCP had undergone modification or improvements, making the evaluation and validation processes doubtful. Currently, the situation is different. As shown, all reports submitted have been revised and improved before being presented as the final versions and put into the public domain. It was also noted that the average time spent on the report validation and submission was one year, with the exception of the Bharati station (India), whose process took four years.

The Bharati station reports also demonstrated the increase of the numbers of revisions made after updating the CEE procedures in 2005. Besides the Indian station, the construction reports of the Korean station and Belarusian station were given more than one recommendation for adjustment. The rigor in the revision process, though important to the environmental protection, can encourage measures to avoid CEE

Table 3
Comprehensive Environmental Evaluation for construction and operation according reports and ATCM.

n	Name	Area	Construction		Country	Local	Type	Report		ATCM
			Start	End				Version	Year	
1	Vechernyaya	108m^2	2015	2018[a]	Belarussian	67°39′S 46°09′E	CO	Final 1st	2015 2013	2014–2015
2	New Chinese Antarctic Research Station	5.528m^2	2015[a]	–	China	74°55′S 163°42′E	CO	3rd	2014	2014
3	Jang bogo	4.661m^2	2012	2014	South Korea	74°37′S 164°13′E	CO	1st	2011	2010–2012
4	Bharati	2.900m^2	2010	2012	India	69°24′ S 76°11′E	CO	Final 1st	2010 2006	2007–2011
5	Kunlun	558m^2	2008	2009	China	80°22′S 77°21′E	CO	Final 2nd 1st	2008 2007 2007	2008
6	Princess Elizabeth	1.900m^2	2007	2009	Belgian	71°57′S 23°20′E	CO	Final	2006	2006
7	Halley VI	2.000m^2	2007	2017	UK	74°25′S 20°45 W	CO	Final	2007	2006
8	Johann Gregor Mendel	288m^2	2004	2007	Czech Republic	63°48′S 57°52′W	CO	1st	2003	–
9	Neumayer III	4.890m^2	2008	2009	Germany	70°37′S 8°22′W	CO	Final	2005	–
10	St. KlimentOhridski	221m^2	2007	2010	Bulgaria	62°38′S 60°21′W	EX	–	–	–
11	Yelcho	400m^2	–	2015	Chile	64°52′S 63°35′W	EX	–	–	–
12	ComandanteFerraz	4.500m^2	2017	–	Brazil	62°5′S 58°23′W	RE	IEE	–	2013
13	Juan Carlos I	1.735m^2	–	2016	Spain	62°39′S 60°23′W	RE	IEE	2008	2009

Legend of the Type: CO – Construction and operation; EX - Expansion; and RE - Renovation.
[a] Prevision of starting/concluding construction.

Table 4
A summary of the environmental impacts identified in the six CEE reports.

Environmental impact	CEE reports					
	Belarusian (2015)	China (2014)	Korea (2011)	India (2011)	UK (2007)	Belgian (2006)
Atmospheric emission	X	X	X	X	X	X
Mechanical impacts on soil/ice	X	X	X	X		X
Noise	X		X	X		X
Waste generation	X	X	X	X	X	X
Waste water	X					
Contamination of soil or ice	X	X	X	X	X	
Loss of scientific value		X		X	X	X
Disturbance of wildlife		X	X			
Introduction of alien species			X		X	X
Light						X

preparation by opting for simpler evaluations.

The CEE is the highest level of EIA, its content is complete and demands the involvement of professionals from various fields of knowledge. The evaluation and official procedure take time, and there is no clear definition of which EIA the construction activities should be submitted to. In this matter, the evaluation of the reference documents shows the absence or simplification of reports on renovation and expansion of facilities, even when buildings have larger areas than those registered in the CEE.

Salamanca (2018) warns that the practice of omitting information is adopted as a way to make easier the approval of EIA documents. Based on the analysis of Table 4 and Fig. 1, it can be inferred that the increase of the IEE for buildings may be related to the motivation of the nations to proceed with the construction of buildings without delays caused by the legal procedures required for the CEE submission.

It is noted that the absence of information from the reports of activities classified as expansion or remodeling of buildings, as well as the presentation of simplified versions can be considered as a negative aspect to the control of the continent's environmental integrity.

3.3. Comprehensive environmental assessment for the construction of scientific stations

The six reports examined were from Belarus (2015), China (2014), India (2011), Korea (2011), United Kingdom (2007) and Belgium (2006).

Initially, the main impacts in the construction phase of new buildings in Antarctica were considered (Table 4).

Formulated from National Academy of Sciences of Belarus (2015), Polar Research Institute of China (2014), Korea Polar Research Institute (2011), National Centre for Antarctic and Ocean Research (2010), British Antarctic Survey (2007) and Belgian Science Policy (2006).

All CEE reports predicted changes in the atmospheric emission and waste generation. As for the impact related to the atmospheric emission, the reports considered that the logistics processes are responsible for the emission of harmful gases. This impact could contribute to regional and global changes in air quality, however, the report from South Korea also expressed concern about the consequences of the impacts on soil and ice contamination, stating that the emissions could be quickly spread to other areas and could change the ecosystem.

In the Korean, British, and Belgium CEE reports it was mentioned that seeds and micro-organism could be introduced by people, vehicles, equipment or materials. Even though the introduction of alien species was taken into consideration in only half of the analyzed reports, the subject had its significance recognized by the CEP through the production of a Non-Native Species Manual (Committee for Environmental Protection (CEP), 2017).The purpose of the document is to establish proceedings to protect Antarctic biodiversity from the risk of unintended introduction of non-native species. According to the CEP, biological invasions that may occur can threaten the biodiversity and the survival of native species, as well as being responsible for alterations in the ecosystem (Committee for Environmental Protection (CEP), 2017).

The light pollution, wastewater and disturbance of wildlife were environmental impacts that have been less addressed on the reports (Table 4). Concerning the light, in most reports it was understood that the scheduled period to begin the construction activities was the summer. In summer, in stations in middle latitude like the Korea scientific station, which is located at 74°S latitude, the sun path does not reach > 45°above the horizon and the sun does not set completely in November, December and January. The solar path in Antarctica is described as having long periods of sunlight, or long periods of light at the construction site, and this fact explains the reason why some reports did not consider light pollution.

In respect to waste water, all the evaluated stations are located close to the coast of Antarctica or to water bodies. It can be added that the polar regions concentrate approximately 69% of the fresh water of the planet, but a great portion of this resource is presented in solid state (Du Plessis, 2017). Under these conditions, in Antarctica, there is no availability or presence of water in the liquid state, ice or snow must undergo processes - abstraction, melting, treatment and distribution - which usually involve the burning of fossil fuels (Montarroyos et al., 2018). Thus, the reports should be more concerned about the elimination of waste, optimization and efficiency of the systems as strategies to minimize the impacts resulting from water consumption.

Regarding the disturbance of the wildlife, for some stations it arises from the logistics systems and vehicles (motorbikes, bulldozers, helicopter and airplane). They consider that the change caused by the disturbance of the ecosystem is temporary or transitory.

It was observed that none of the station reports included all the environmental impacts resulting from the construction of buildings in Antarctica. As expected, in each planning there are specificities related to the size of the building, architectural concept, location, materials, logistics, and construction techniques, among others. It is also worth noting that this research involved the latest published versions of the EIA reports, not necessarily the final version approved by the committee. In this sense, some reports have been undergoing changes and improvements, such as the reports of Korea and China.

Concerning the analysis of the requisites, according to the reference data of the reports, it was observed that, in Antarctica, there are significant differences related to the metrics proposed by the SBTool, for example, the duration of the impact. For better analysis of the data and for the definition of the parameters and metrics for the continent, comparative tables according to the standard SBTool were chosen.

Knowing that the SBTool generic parameter should be adjusted for the Antarctic region, a comparative analysis of the metrics used in SBTool and the metrics exposed on the CEE reports was done. The results showed that while in dense urban centers worldwide the impact duration requirement considers reference values > 1 year, in Antarctica the minimum impact duration is set in minutes. It should be noted that the initial reference of duration, bounded by most reports, was less than

a few days.

Such delimitation of nations in relation to the duration of impacts represents a concern for the Antarctic environment and the scientific research carried out in the area, where all impacts, even transitory ones, should be considered.

The reference values of the extent presented metrics similar to urban areas. Regarding the intensity while SBTool values range from minor to major, the published CEEs included data of greater magnitude, mostly addressing values from very low to very high.

Regarding the probability requisite, it shall be noted that the SBTool scorecard does not assess the probability of occurrence, maybe because the evaluation of future impacts or probability of occurrence involves uncertainties. In order to achieve results and metrics, the European Union (2017) suggests the use of the magnitude and sensitivity of the environment as a method to validate data.

In Antarctica, fulfilling the probability requisite can serve as a warning for the development of measures to prevent or mitigate the impact. Most of the metrics are compatible with globally recognized environmental assessments, ranging from unlikely to certainty of occurrence.

When analyzing all the requisites of the reports, it can be highlighted that there are gaps in the Protocol and Annexes, which do not contain a predetermined list of possible impacts of all construction activities on the continent, or a structure evaluation that allows standardized data.

Since there is no standardized procedure specified by the CEP, these requisites and benchmarks can serve as a parameter for EIA, CEE or IEE. In this regard, in the ATCM of 2017, the Committee agreed to update the procedures for the elaboration of the CEE, encouraging the identification of all environmental risks of the activities, as well as the presentation of mitigation measures. Also, the formulation of standardized procedures was suggested by the parties, aiming at ensuring that the published CEEs could be made publicly available with the highest level of data accuracy based on practices of excellence (Antarctic Treaty Consultative Meeting (ATCM), 2016a, 2016b).

Thus, based on SBTool generic and analyzed reports, it was possible to identify the probable impacts attributed to the construction activities of Antarctic buildings, as well as the parameters that allow the formulation of a standard methodology for the continent. The environmental impacts, assessment requisites and the most frequent parameters assigned by the nations were organized according to Table 5.

The reference parameters were organized in a scale of values from 1 to 5 (1 for effect of lower significance to 5 for effect of greater significance). The use of numerical scale helps the quantification of qualitative data.

Therefore, the table presented can serve as an instrument for the standardization of information specific to Antarctica, as well as contributing to the establishment of environmental impact weights, formulation of the environmental assessment method and verification of the indicators for sustainable construction in Antarctica.

3.4. Application of the proposed Antarctic scorecard, proposal of the evaluation instrument and discussion of the results

The contents of six CEE reports on the construction of scientific stations in Antarctica, published in the public domain were assessed using the proposed SBTool scorecard (Table 6).

Formulated from National Academy of Sciences of Belarus (2015), Polar Research Institute of China (2014), Korea Polar Research Institute (2011), National Centre for Antarctic and Ocean Research (2010), British Antarctic Survey (2007) and Belgian Science Policy (2006).

The first result obtained was the fact that there was no agreement in the weighting of the requisite duration of the impact of atmospheric emissions. The stations of India and Belgium considered that atmospheric emissions were derived exclusively from the burning of fossil fuels in the transportation of building materials processes in Antarctica. In the reports of the Belarusian and Korea stations, atmospheric emissions also referred to the construction process, where the impact was due to the consumption of fossil fuels to generate the energy necessary to use the equipment on the site. As for the stations of China and UK, besides the logistics process, they also considered the atmospheric impacts in the phase of operation of the building (Table 6).

Given the divergence in the origin of the impact, it was not possible to come up with a conclusive result. Regarding this matter, there was also a concern expressed about the scope of themes and the lack of standardization in the preparation of the CEE report.

On the subject of soil and ice contamination impacts, the same thing happened. While the CEE of Belarus expressed concerns about the dispersion of oil in the ocean and groundwater, other reports addressed contamination from solid waste dumping. The UK report discussed contamination of the ocean regardless of possible soil/ice contamination.

In the intensity requisite, it was noted that all the impacts of the construction had the intensity rating scales estimated as low or very low. In the urban area worldwide, it is understood that the construction activities cause impacts of high intensity and interfere negatively in the natural environment configuration (Babak, 2017). In Antarctica, the result can be a reflection of the strict control and environmental monitoring of the construction activities, in which, for the planning of new buildings, impacts of great intensity are not allowed. In regard to this matter, it is possible that the nations underestimated the intensity of impacts in order to gain the report approval or to accelerate the CEE process. On the other hand, these results can also imply that the nations used global scales or scales of their own countries for the assessment in Antarctica, which may not represent that specific area.

On the probability of impacts, most nations have stated that the probability of impacts such as atmospheric emission and loss of environmental value is inevitable. In addition to this fact, there is a high probability of events such as mechanical impacts and contamination of soil or ice. In this regard, the result highlights the need for compulsory presentation of activity reports containing not only impact assessment but also compensatory or mitigating measures.

Atmospheric emissions in Antarctica can be caused by emissions of greenhouse gases and particles from engines, generators and incineratorsequipment. This, in addition to influencing air quality, has potentially a negative impact on the marine and terrestrial environment, lakes, soil and ice (Antarctic Treaty Consultative Meeting (ATCM), 2016a, 2016b). In the analyzed reports, only the impacts resulting from atmospheric emissions extend to the regional sphere. No other impact has its extension greater than the local one. The extension

Table 5
Proposed Scorecard for Antarctica based on the metrics exposed in the CEE reports.

Extent of potential effect (Ep) 1 to 5 points	Duration of potential effect (Ed) 1 to 5 points	Intensity of potential effect (Ei) 1 to5 points	Probability of potential effect (Pe) 1 to 5 points
1. AreaSpecific	1. Minutes/ days	1. Very low	1. Unlikely
2. Local	2. Weeks/months	2. Low	2. Low
3. Regional	3. Years	3. Moderate	3. Medium
4. Continental	4. Decades	4. High	4. High
5. Global	5. Centuries	5. Very high	5. Certain

Table 6
Application of the proposed scorecard for Antarctica based on the CEE reports.

Environmental impact	Duration of potential effect (Ed) 1 to 5 points						Extent of potential effect (Ep) 1 to 5 points						Intensity of potential effect (Ei) 1 to 5 points						Probability of potential effect (Pe) 1 to 5 points					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Atmospheric emission	2	4	2	3	3	5	1	2	3	3	2	3	2	3	2	3	2	2	3	5	4	5	4	5
Disturbance of wildlife	-	1	-	-	-	1	-	1	-	-	-	1	-	1	-	-	-	1	-	2	-	-	-	4
Contamination of soil or ice	2	4	4	4	4	4	1	1	1	2	2	1	3	1	2	2	4	1	3	4	2	2	4	4
Mechanical impacts on soil/ice	2	3	2	2	2	-	1	1	1	1	2	-	2	1	3	2	2	-	4	5	4	5	4	-
Loss of scientific value	-	3	-	4	-	3	-	1	-	2	-	2	-	1	-	1	-	1	-	5	-	5	-	5
Waste generation	2	4	2	3	4	4	2	1	1	2	2	2	2	1	2	2	2	2	2	5	2	2	4	5
Contamination of ocean	-	-	-	2	3	4	-	-	-	1	2	1	-	-	-	2	2	2	-	-	-	5	4	5
Noise	2	-	2	3	4	-	1	-	2	2	2	-	2	-	1	2	3	-	3	-	2	5	2	-
Light pollution	-	-	-	-	4	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	3	-
Waste water	2	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-

Legend of the nations: A- Belarus; B- China; C- Korea; D- India; E- Belgium; F- UK
Legend for color scale:
Lower significance | 1 | 2 | 3 | 4 | 5 | Greater significance
Absence of color represents impact not evaluated

Table 7
Factor and weight of the environmental impact in Antarctica.

Environmental impact	FkA	FkB	FkC	FkD	FkE	FkF	W	Primary system directly affected (Es)	Es Value	Reference value
Waste water	8	0	0	0	0	0	0.005	Water resources	0.081	1
Contamination of ocean	0	0	0	20	48	40	0.076			
Noise	12	0	8	60	48	0	0.090	Fauna and flora	0.128	2
Light pollution	0	0	0	0	48	0	0.034			
Disturbance of wildlife	0	2	0	0	0	4	0.004			
Loss of scientific/ environmental value	0	15	0	40	0	30	0.060	Environmental value	0.209	3
Waste generation	16	20	8	24	64	80	0.149			
Contamination of soil or ice	18	0	16	32	128	16	0.147	Soil and ice	0.222	4
Mechanical impacts on soil/ice	16	15	24	20	32	0	0.075			
Atmospheric emission	12	120	48	135	48	150	0.360	Atmosphere	0.360	5

of potential effects, together with the probability of their occurrence, raises an alert for the continent's environmental integrity. Consequently, the result points to the importance of the preparation of official documents for the prevention of impact and orientation of procedures of low emissivity.

Among the impacts with a low score or low index of evaluation, the impact "disturbance of wildlife" had only two evaluations by China and UK. The two reports that responded to the impact issue showed an interference caused by vehicles that lasted only a few days in the specific area, characterized by a very low intensity impact. The stations that did not score stated that the impact on the ecosystem was transitory, which meant that the evaluation was not obligatory for the CEE report. However, there was incoherence when justifying the duration, since the reports allowed the evaluation of transitory impacts or impacts of short duration.

The assessment of the impact "disturbance of wildlife" is complex and comprehensive. It is essential to investigate the cause of the disturbance to the ecosystem as well as the proximity to especially protected areas, and to support species monitoring.

The reports on "loss of environmental value" were unanimous regarding the results of probability and intensity. The reports recognized the impact as unavoidable or certain and with low intensity. On this issue, Bastmeijer and Roura (2008) stated that there were methodological difficulties in the evaluation of environmental values on the continent. For them, the environmental assessment carried out under this requirement was superficial and not in conformity with the Protocol content.

There are many countries concerned about the poor quality or inaccuracy of the information included in the EIA reports in the world. The lack of reasoning when filling the report can lead to legislative problems besides influencing the commitment of the nations to the environmental responsibility (Morgan, 2012). Therefore, for all possible impacts assessed in Antarctica, particularly for the impact of "loss of environmental value", the recommendation is to conduct careful inspection and the adoption of close validation of the EIA reports including values presented by the nations.

Based on the algorithm 2 ($Fk_1 = Ep \times Ed \times Ei \times Pe$), adapted from the internal SBTool system, the values assigned by the nations for each requisite (Table 8) were multiplied to obtain the environmental impact factor in Antarctica (Fk). Based on this result it is possible to state that, for the nations involved, the most important impact on the Antarctic environment is "Atmospheric emissions" with 0.360, followed by "Waste generation" with 0.149 and the "Contamination of soil or ice "with 0.148. On the other hand, the impacts of lower weight are "Disturbance of wildlife" with 0.004, and "Waste waters" with 0.006 (Table 7). In addition, by the sum of the individual results it was possible to obtain the percentage equivalent to the weight of the impacts (W), according to expression 3. The sum of the weights must be equal to 1.

In order to organize a quantitative evaluation, the Primary system directly affected (Es) was organized in ascending order. Like the other requisites, it was necessary to associate the results to a reference value from 1 to 5.

As expected, due to the correlation between impact weights and

Table 8
Scorecard and weighting factors for Antarctica.

Extent of potential effect (Ep) 1 to 5 points	Duration of potential effect (Ed) 1 to 5 points	Intensity of potential effect (Ei) 1 to 5 points	Probability of potential effect (Pe) 1 to 5 points	Primary system directly affected (Es) 1 to 5 points
1. Specific area	1. Minutes/ days	1. Very	1. Unlik	1. Wateresources
2. Local	2. Weeks/months	2. low	2. low	2. Fauna and flora
3. Regional	3. Years	3. Moderate	3. Medium	3. Environmental value
4. Continental	4. Decades	4. High	4. High	4. Soil and ice
5. Global	5. Centuries	5. Veryhigh	5. Certain	5. Atmosphere

primary system, the Primary System directly affected (ES) with the highest score was the "Atmosphere" with 0.360, followed by "Soil or ice" with 0.223 and "Environmental value" with 0.208, while the lowest score was represented by "Water Resources" with 0.081.

Regarding the obtained results, the complexity to organize the impacts according to the Es is emphasized, since some impacts can affect one or more primary systems. For example, the impact "Waste generation" can affect either "soil or ice", "fauna and flora" or "water resources". Thus, it is advisable to fully clarify the origin and the stages of the impact-generating activity in the CEE process.

One of the main results of the research is the scoring table with the pre-established values, which can contribute to the enrichment of the environmental assessment data in Antarctica (Table 8).

This framework serves as an instrument for quantification and standardization of data, encouraging further knowledge about the possible environmental impacts of construction activities in Antarctica. Therefore, it is suggested to fill in the columns with indicators.

With the weighting factor scorecard, nations must fill 1 to 5 in the columns corresponding to the requisites for each proposed indicator. Based on algorithm 2 and 3, it is possible to obtain the Fk and the weight of the indicator (W). The result should quantitatively expose the evaluation of the indicator of major and minor significance on the continent, considering the four requisites and their interference in the primary system defined for Antarctica.

For the nations, the use of the scorecard and its results which might replace the CEE obligatory item "impact matrix", will serve as a basis for decision-making aimed at reducing environmental impacts. The weighting factor can allow comparisons, besides contributing to standardizing the evaluation process and the content of the evaluation. For the committee, it can help speed up the validation process and the report statements, in addition to making the report contents clearer. It can also provide metrics for good practices and show disagreements with the predicted impacts.

In both cases, quantifying the data, by filling up or evaluating the scorecard based on the SBTool, may help identify gaps in the assessment, show which one is the best indicator to work on eliminating impacts or on proposing measures to mitigate them, and collaborate on the transparency of the process in order to make the assigned priority to preserving the Antarctica environment clear.

4. Conclusion

Although the CEE process of the impacts of construction in Antarctica has limitations, it is an important instrument that contributes to the preservation of the environment and should be an integral part of the decision-making and updating of the Antarctica legislation.

The investigation and analysis of the EIA report data pointed to the necessity of improvements in the CEE process. Among the possible improvements, and standardization of CEE content, suggestion of the requisites and primary systems to be evaluated were highlighted, combined with the basis of the methods used for the evaluation by the nations, besides the identification of items that cannot be applied to the specificity of the new stations.

As a result, it was also observed that there was the need to update the environmental assessment procedures in order to consider the detail of the source of the impact, as well as the elaboration of guidelines on how to conduct comprehensive assessments which included analyses of issues such as "loss of environmental value" and "atmospheric emissions". Another topic that requires attention is the importance of a systematic study of the identified environmental impacts, as well as the presentation of monitoring programs and mitigation measures for the impacts identified as inevitable or very likely to occur on the continent.

The proposed methodology for the formulation of a scorecard based on the SBTool generic as an instrument for evaluating and standardizing data adapted for use in the Antarctic region. It should be noted that the study conducted for Antarctica, through a methodology that involves the adaptation of an internationally recognized tool, can foster comprehensive environmental assessments with data integrity and transparency in the process, in addition to allowing adjustments that contribute to the evaluation and preservation of other areas of environmental protection.

As future work, the following issues are suggested: the definition of indicators followed by the application of the framework for sustainability assessment in the built environment, analysis of environmental assessments in the operation phase, and formulation of procedures to support the updating of the Protocol content.

Furthermore, the use of this instrument by groups of independent experts to evaluate the publically available reports and to assess other impacts of human activities (e.g. logistic operation) on Antarctica should be considered as well as adapting it to other areas of environmental protection.

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