SOCIAL SUSTAINABILITY IN THE LIFE CYCLE OF CHILEAN PUBLIC INFRASTRUCTURE

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ABSTRACT: To enhance concern for the social aspects of sustainability and to delineate the criteria to be considered at each stage of the life cycle of an infrastructure, this paper aims to determine the relevance of a set of criteria that evaluate social sustainability throughout the life cycle of a public civil infrastructure. This research presents the results of a case study applying the Delphi method to 24 Chilean experts consulted in a series of three rounds. In addition, binomial statistical tests and Kendall's coefficient were used to show the convergence of the experts. Thus, it was identified that of 36 initial criteria assessed at each stage of the life cycle, the consideration of 20 is required at the design stage, 29 at the construction stage, 33 during operation and 27 at demolition. The most relevant criteria, per life-cycle stage, were: "Stakeholder Participation" (design and demolition stages), "External Local Population" (design stage), "Internal Human Resources" (construction and demolition stages), "Macro-Social Action" of "Socio-Environmental Activities" (construction stage), and "Macro-Social Action" of "Socio-Economic Activities" (operation stage).

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INTRODUCTION

At the beginning of the 1970s, the concept of sustainable development had already been established as “economic development that can be of benefit to current and future generations without damaging the planet’s resources or biological organisms” (NEPA 1969). Years later, the Brundtland Report (WCED 1987) broadened this definition, and the development concept was transformed into a more qualitative, complex, multidimensional and intangible concept. This focus made economic, social and environmental concerns compatible, without jeopardizing the development opportunities of new generations or the future life of the planet (WCED 1987; UNCED 1992). In the last 30 years of the 20th century, the discussion on sustainable development emphasized the need to bequeath a better natural world for future generations, whereas only at the end of the century did the international community begin to understand that the goal must be to increase human abilities (Anand and Sen 2000).

In 1992 the construction industry initiated action plans proposed by the United Nations and its organizations through the “Agenda 21 for Sustainable Construction in Developing Countries”. This plan was signed at its inception by more than 178 countries in the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (UNCED 1992). Since then, awareness of pursuing an agenda oriented toward sustainability has been heightened, and this includes the social considerations throughout the life cycle of the project: design, construction, operation, and demolition (Boyle et al. 2010; Pellicer et al. 2014; Venegas 2003). However, this has not been enough, and the fundamental limitation of sustainability nowadays is clear: it tends to concentrate on the biophysical and economic considerations of the constructed environment, without adequate consideration of the social aspects involved (CIB 2002; Torres-Machí et al. 2014 and 2015). Indeed, some public sector projects have not sufficiently considered certain elements of social performance, which should be their main objective (Shen et al. 2010).

Not including the social dimension in an infrastructure's development will have detrimental effects in the short and long term that determine the results of the project. In the mid-short term, the dynamics of infrastructure development with the growing participation of various actors (Bakht and El-Diraby 2015) and their interactions involves emerging risks that challenge the achievement of the project results (Yepes et al. 2015), when prompt social treatment is not preconceived (Naderpajouh et al. 2014). These dynamics generally dominate other potential risks, such as the technical and economic complexities of the project (Alarcón et al. 2011). On the other hand, in the long term, not adequately considering the social aspects may have detrimental effects that can jeopardize the quality of intra-generational life (Lehmann et al. 2013; Axelsson et al. 2013).

Today the definition of the criteria that comprise social sustainability in construction projects has yet to be clearly delineated, depending on the application contexts, the participants' perspectives and the life cycle stages (Bakht and El-Diraby 2015; Labuschagne and Brent 2006; Pellicer et al. 2014; Valdés-Vásquez and Klotz 2013). In Chile in particular, despite recent initiatives adding concern for the social aspects (Government of Chile 2013), the focus remains on conceptual guidelines with a tangential orientation toward sustainability through social responsibility and not the social impact of the infrastructure.

A literature review was conducted to examine the social impacts addressed by various authors since 1970. Among the studies, a structure of social sustainability was identified; it focuses on the social impact that business initiatives exert on society (Labuschagne et al. 2005). It broadly covers the impacts surveyed and it has also been used in construction studies (Flores et al. 2013; Huang et al. 2012; Lang et al. 2007). However, making decisions that include social aspects depends on the points of view of the actors involved as well as on the contexts of application (Bakht and El-Diraby 2015; Vanclay 2002; Valdés and Klotz 2013). Therefore, any structure of social sustainability must be clarified and defined (Labuschagne and Brent 2006; Slootweg et al. 2001; Valdés and Klotz 2013) during the life cycle stages (Boyle et al. 2010) and the incidence that the construction projects have in this life cycle must be explained from the social viewpoint (Valdés and Klotz 2013).

Thus, this article aims to: i) identify the criteria of the social sustainability structure best suited to the nature of each stage of a public infrastructure's life cycle; and ii) determine the degree of relevance of each criterion in the development of this infrastructure. These goals are limited to public infrastructure and a number of experts consulted regarding the Chilean context. This paper includes the background (next section) to define the social sustainability criteria used as well as subsequent sections describing the method, results, discussion and conclusions of the research.

SOCIAL SUSTAINABILITY FACTORS AND CRITERIA

In the process of identifying social sustainability guidelines, this study included a review of previous contributions to establish the social impacts or factors, as well as the criteria that address these social impacts on a public civil infrastructure project during its life cycle. To achieve this goal, previously, two basic concepts have to be defined: social impacts (or factors) and criteria. Social impacts are "all social and cultural consequences to human populations of any public or private actions that alter the ways in which people live, work, play relate to one another, organize to meet their needs, and generally cope as members of society" (ICPGSIA 1994, page 107); these impacts are dealt with in the next paragraph. On the other hand, the rest of the section handles some approaches to criteria found in the literature review, considering the simple definition of a criterion as the cause for making a decision from a social viewpoint.

First, the literature review identified the main articles and international norms focused on social aspects or factors, and 110 contributions were obtained, beginning in 1970. These documents were organized to fulfill three objectives: conceptualization of the aspects (Hill and Bowen 1997; Vanclay 2002; Valdés and Klotz 2013), methodological applications and indicators (Azapagic 2004; Labuschagne et al. 2005; Fernández-Sánchez and Rodríguez-López 2010), and policy recommendations for evaluation (ICPGSIA 1994; ISO 2010; GRI 2013). With all the impacts compiled from the literature review, the research team assembled nine categories of social impacts or factors, subdivided in 20 groups, according to their conceptual affinity; the columns in Table 1 displays these categories and groups. The research team made use of a focus group to validate them; this focus group was formed by the research team, as well as three additional members, all of them professors with more than 20 years of academic and professional experience. Later on, the contributions were classified according to these 20 groups. Table 1 shows (in rows) the most relevant contributions: those that deal with 40% of the social impacts, at least; this percentage of coverage is calculated dividing the number of factors in the article by the total identified, in %.

<TABLE 1 HERE>

Regarding the criteria, during the 1980s authors like Finterbuch (1985) established the first methodologies and aspects to consider when assessing the social impacts of construction projects. Nevertheless, since the 1990s social criteria have been further defined and specified (ICPGSIA 1994; Burdge 1994). From the outset, the criteria sought to overcome the conditions of poverty associated with shortages of resources (Hill and Bowen 1997); this has evolved in our era into social vulnerability, which encompass better the aspects to be considered (Vanclay 2003).

In the last decade, Vanclay (2002) has delved more deeply into the effect of the social aspects, and differentiated between those which involve a direct impact for society and those that are agents of change which, under certain circumstances, may involve some social risk. This differentiation complements the studies by Slootweg et al. (2001), who established an iterative integration model of the social and environmental impacts; human interventions imply change processes that subsequently become impacts.

By the beginning of the 2000s, these criteria were already being adapted to the review of particular cases and integrated into methodological proposals that aimed to involve social aspects in sustainability assessment (Azapagic 2004; Shen et al. 2010; Ugwu and Haupt 2007; Fernandez-Sánchez and Rodríguez-López 2010). Thus, a large number of the aspects formulated in the 1990s were included in more comprehensive studies developed by Labuschagne et al. (Labuschange et al. 2005; Labuschagne and Brent 2006 and 2008). These studies proposed a conceptual structure of the social dimension that deals with the impacts of the company on the social systems in which it operates. The structure of social sustainability integrates the Global Reporting Initiative, the United Nations Sustainability Indicators, the Wuppertal Sustainability Indicators, and was contrasted against more than 31 international regulations and scientific studies (Labuschagne and Brent 2008).

In this study, the criteria established by Labuschange et al. (2005) were used as a foundation, insofar as these were adequate for public infrastructure initiatives. There are three main reasons to use these criteria as the point of departure: (a) they present the highest level of social impact coverage (80%) among the literature reviewed (see Table 1); (b) they have been used in methodological applications (Flores et al. 2013; Huang et al. 2012; Lang et al. 2007); and (c) they were drafted on the basis of an exhaustive review and contrast with regulations and studies by authors who have addressed this topic in the last 20 years. Thirty-one criteria integrate social sustainability, classified into four macro-groups: internal human resources (10 criteria), external local population (12 criteria), social participation of stakeholders (4 criteria), and social activities at a regional or national level (5 criteria).

RESEARCH METHOD

As indicated in the Introduction, this research intends to identify and prioritize the criteria of the social sustainability structure for each stage of the life cycle of a public infrastructure. In order to do so, the research process follows the steps summarized in Figure 1. First, the impacts or factors were obtained from the literature review explained in the previous section, by means of grouping them in 20 groups; this process was validated by a focus group. After analyzing previous contributions, the work of Labuschange et al. (2005) was taken as the point of departure of the social sustainability criteria. The next step is to enhance prioritize and justify the social sustainability criteria suitable for each stage of the life cycle of a public infrastructure implementing the Delphi technique (explained in the following sub-section and Table 3). Finally, using semi-structured interviews with the same members of the panel, the previous results are confirmed and justified.

<FIGURE 1 HERE>

The Delphi Method

The Delphi method is a technique of structured and systematic communication useful to achieve these objectives, because it is a tool that can address complex conceptualizations involving reflective and critical analysis (Cortes et al. 2012; Sourani and Sohail 2014; Alshubbak et al. 2015), while maintaining the freedom of judgment of specialists who do not interact (Hallowell and Gambatese 2010). Delphi is based on the principle that decisions from a structured group of individuals are more accurate than those from unstructured groups (Rowe and Wright 1999). The Delphi technique has recently come to be applied in many complex situations where a consensus is required (Hallowell and Gambatese 2010; Cortes et al. 2012; Alshubbak et al. 2015). Application of the Delphi technique involves specific steps (Fig. 2). For a rigorous implementation, this article followed the guidelines proposed by Hallowell and Gambatese (2010) and Cortes et al. (2012), including the expertise and number of experts on the panel, feedback process and number of rounds.

<FIGURE 2 HERE>

Selection of the Expert Panel

The success of the Delphi method depends first of all on the selection of the participants (Hallowell and Gambatese 2010). Accordingly, 33 potential experts were preselected, residents in the geographical study area (Chile) and with experience and training in the area of "Public Civil Infrastructure Development" (Profile 1) and "Socio-Environmental Development" (Profile 2). The expert selection process was conducted on the basis of two criteria:

- According to Hallowell and Gambatese (2010), each panelist had to fulfill at least four of the following requirements: (a) primary or secondary author of at least three peer-reviewed journal articles; (b) invited to speak at a conference; (c) member or chair of a nationally recognized committee; (d) at least 5 years of professional experience in the construction industry; (e) faculty member at an accredited institution of higher learning; (f) advanced degree in the field of civil engineering, construction management, or other related fields (minimum BS); or (g) professional registration.
- Additionally, the expert selection was validated from a self-evaluation of the level of competence in the research topic, through the technique proposed by the Russian State Committee for Science and Technology (Oñate et al. 1998); with this technique, each expert as scored according to two parameters: knowledge and argument. The average of these two parameters gives the level of competence of the expert. Table 2 explains the computation.

<TABLE 2 HERE>

The definitive expert panel had 24 members. The expert panel is characterized in Table 3 according to its profile. Considering the criteria provided in Table 2, the individualized validation of the expert panel's competence is checked; all the experts can be considered as highly competent, as shown in Table 4.

<TABLE 3 HERE>

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Questionnaire and Measurement Instrument

An initial questionnaire was designed on the basis of the literature review, the criteria of the social sustainability structure proposed by Labuschagne et al. (2005), and prior consultation with three experts in the subject area using the same focus group. The questionnaire requires information that addresses two main questions:

1. Which social sustainability criteria affect the life cycle stages of a public civil infrastructure (design, construction, operation, and demolition)?
2. What is the level of significance that each social sustainability criterion has with respect to the life cycle stages of a public civil infrastructure?

The responses were quantified using two measurement instruments:

- The answers associated with question 1 were valued on a dichotomizing scale (Agree-1 or Disagree-0) with respect to the experts' consideration of each social sustainability criterion at each stage. The responses were processed through a binomial nonparametric test that guarantees the reliability and convergence of the opinions according to the statistical significance of the probability that agreement is reached (Siegel 1983).

- The answers associated with question 2 were valued on a 5-point Likert scale that measured the degree of relevance (High-5, Remarkable-5, Moderate-3, Low-2 or Insignificant-1) that each criterion confers on social sustainability among the life cycle stages. To measure the consistency of the experts on the order of significance, Kendall's coefficient of concordance (or Kendall's W) was determined. This nonparametric statistic was used to evaluate the statistical significance of the order granted by the experts (Singh et al. 2009).

Survey Process

A description of the study method and objectives was presented to the potential experts through an invitation via e-mail. Once they had agreed to participate, the facilitator arranged an individual meeting by video conference. During this meeting questions were answered, and further details of the study were provided regarding the conceptualization of the aspects involved and the dynamics of work. The questionnaire was sent and the experts' opinions were processed, analyzed and taken into account in the following round.

Three rounds were needed to reach a consensus with respect to the desired objectives and to ensure accuracy and rigor in the study; the process was stopped when more than 50% of the experts agreed, obtaining statistical significance in the binomial test, as explained in the Results section. Feedback to the experts entailed informing the group's points of view with a report of the results via e-mail before proceeding to the following round. The experts then received a new questionnaire; they were asked to reconsider their responses, particularly in those cases where information provided in the previous round had not significantly demonstrated a consensus on the variable under discussion.

When consensus was achieved in the third round, the facilitator arranged a semi-structured individual interview with each expert via video conference, during which he/she was asked to confirm, first, and justify, later, the level of significance of each criterion for the infrastructure's life cycle. This can be considered as a fourth round of validation of the Delphi method.

RESULTS

The results of the Delphi method are presented in Table 5, which identifies an infrastructure's life cycle stages with the criteria affecting social sustainability. The table not only shows the order of general importance of the social sustainability criteria for each stage (scale from 1st to 4th place), but also the mean degree of relevance (Likert scale from 1 to 5) of each profile defined in Table 5. The order of importance assigned by the experts reached statistical validity for all the criteria evaluated. Once the first round of the questionnaire was agreed upon by the panel, five criteria were incorporated in the second round at the panel's suggestion and reviewed by the research team (Criteria 1.11 to 1.15).

<TABLE 5 HERE>

In light of the responses and considering the criteria at each stage of a public civil infrastructure's life cycle, the statistical validation of the binomial test with 5% bilateral error identified the criteria which, according to the experts, had to be taken into account. Two sets of results were obtained from this analysis: (1) approved criteria, i.e., evaluations with statistical significance and agreement percentages over 50%; and (2) rejected criteria, i.e., evaluations with statistical significance and agreement percentages under 50%. Table 5 shows the results of the criteria included by the experts according to the applicable stage. Of the 36 criteria evaluated at each of the four stages (144 evaluations), 75.7% (109) were approved and 24.3% (35) were rejected. The aspects not included in some of the stages are consistent with the group decision of the 24 experts, as well as the selection of the profiles separately. The criteria that were not rejected and their order of importance were obtained according to the experts' experience, assuming a normal infrastructure development dynamic, and it may be that with certain project characteristics some criteria might not be pertinent. In addition, the general order of importance in the life cycle is statistically consistent for all the criteria evaluated with Kendall's W about the 24 experts' opinion (Table 5).

The order of importance of each stage is consistent in almost every case with the degree of relevance of each profile that the expert panel recommended (Table 2). However, the profiles disagreed in the assessment of four criteria:

- "Health and Safety" was considered more important in the construction stage, instead of the demolition stage, for social-oriented experts (profile 2).
- "Training, Further Education and Career Development" was scored higher by construction-oriented experts (profile 1) in the operation stage.
- "Innovation and Research" was rated first in the design stage for both profiles, but operation was rated second by social-oriented experts (profile 2) instead of construction (profile 1).

- “Provision of Information” in the construction stage was more important for social-oriented experts (profile 2), ahead of design (the most important for profile 1).

DISCUSSION

According to the experts surveyed and interviewed in this study, not all the stages of an infrastructure’s life cycle contribute equally to the categories of social sustainability (internal human resources, external local population, activities at regional or national level and stakeholder participation). In fact, it was found that activities during the design stage significantly affect most of the criteria of the “Stakeholder Participation”, which is consistent with Valdés and Klotz (2013); in this stage, decisions influence highly the permanent conditions of use of the infrastructure. The remaining categories, although subject to impact, have fewer criteria affected. Similarly, the activities in the construction stage have a greater influence on the categories of “Internal Human Resources” and “Macro Socio-Environmental Activities” due to the higher impact on the built environment; this agrees with the results in Naderpajouh et al. (2014). The operation stage influences the “Macro Socio-Economic Activities” and “External Local Population”, which is associated with the functioning of the human dynamic systems presented by Boyle et al. (2010); as these authors infer, facets such as commercial profit, tax collection, capital improvement, and benefits for the local economy, are aligned with this proposal. The demolition stage impacts the “Stakeholder Participation”, especially with regard to the demolition planning phase but also the “Internal Human Resources” after the process of construction.

Based on the results in Table 5 and the experts' justification in their decision-making, certain logics of transcendence were postulated. In this regard, experts stressed the direct impact of construction and demolition processes on the "Job Opportunities" and "Job Benefits", as well as the relevance in certain works of conservation infrastructure (e.g. road works); in this sense, ILO (2015) points out construction stage as the fourth economic activity worldwide contributing to employment (8.4%.), whereas Menéndez (2003) shows the importance of regular maintenance during the operation stage for local employment generation. On the other hand, workers' "Health and Safety" conditions are highly valued at every stage, with construction and demolition being the most relevant, which is consistent with the findings of Ugwu and Haupt (2007). In addition, the employee's development capacities ("Training, Further Education" and "Career Development") present transverse trends to the development of the infrastructure (Labuschangne et al. 2005). However, the experts considered that the processes of the design stage provide better conditions for promoting "Innovation and Research"; these estimations are in line with the conclusions drawn by Valdés and Klotz (2013).

The experts were of the opinion that some "Employability Practices" ("Disciplinary Practices or Conditions of Labor Contract") are consistent with ISO 26000 (2010), but they specified that their importance becomes more significant when the stages are shorter. During the stages of longer duration or stages with fewer participants, the relationships of trust and responsibility become more important to the functioning of the infrastructure than organizational or contractual norms. This notion is in line with Alarcón et al. (2005), whose findings show the relation between motivation, trust relationships and the conditions enable the growth of the individual in a working environment in Chilean construction companies. In particular, the experts suggested that in hiring and promotion at the design, construction and demolition stages, they prioritize ability, experience and team work, which was also recognized by Alarcón et al. (2005). The experts added that the requirement of the project in a limited time reduces possible discriminatory actions ("Inequality") on human resource management. Additionally, in the Chilean construction sector, the experts referred to the unlikelihood of hiring people who do not fulfill the conditions established by labor legislation ("Work-Related Sources"), which is why point 1.10 of Table 5 was not included.

In general terms, the experts believed that most of the criteria related to the "Work Climate" (1.11 to 1.15, Table 3) go beyond the effects of the construction stage, as these require a longer period of time to be effective. In keeping with the considerations of Valdés and Klotz (2013), the experts believed in the importance of work teams being "Aware of Sustainability" when they create and plan a project.

From the experts' point of view, the conditions that affect the community's "Human Capital" are also affected by the design stage, because it is here that decisions are made that will impact the future surroundings (Valdés and Klotz 2013), and the operation stage is where those impacts become permanent (Gilchrist and Allouche 2005). According to the experts, this pattern can be likened to most "Productive and Community Capital" criteria. They also emphasized the effects on "Private Property", i.e. expropriations or variation in the value of the building. In the latter case it tends to be significant prior to materialization, as a result of speculation on the variations in demand according to the experts and in fact previous case studies provide evidence of this (Egre and Senecal 2003; Lockie 2009).

According to the experts, “Stimulation of the Senses” and “Cohesion and Identity” are criteria affected by community and family interaction with the infrastructure in use, just as Vanclay (2002) also associated these criteria to habitability and family life indicators.

“Macro-Social Activities” are those with a regional economic impact through tax collection or commercialization, which is mainly significant during the use of the infrastructure, according to the expert’s opinion and the results of Fernández-Sánchez and Rodríguez-López (2010). Other “Macro-Social Activities” recognized by the experts are the environmental practices more heavily associated with the construction stage, although the authors recommended their uniform monitoring during the infrastructure’s life cycle (Fernández-Sánchez and Rodríguez-López 2010; Labuschagne and Brent 2008).

According to the experts, democratization implies that actors participate in an informed context (“Provision of Information”), which would allow relevant contributions from the stakeholders. Thus, the design and pre-demolition stages are crucial in terms of how the delivery of information and “Consideration of Opinions” (feedback) are handled; this idea is also highlighted in the study by Valdés and Klotz (2013). The experts believed that achieving democratization also requires “Empowerment” (or a commitment to involvement) throughout the development, this being consistent with other authors and policies (Fernández-Sánchez and Rodríguez-López 2010; ISO 2010). They all indicate the planning and design stage is the one where the decisions are made.

CONCLUSIONS

This article describes the process and results of the research conducted to select the criteria that contribute to social sustainability in the development of a civil infrastructure for public use in Chile. The contributions of this article focus on the criteria selected to contribute to the social sustainability of an infrastructure and will determine an order of relevance among the stages of the life cycle. The finding allow us to conclude that there are 20 criteria in the design stage, 29 in the construction stage, 33 in the operation stage and 27 in the demolition stage, which constitutes a maximum of 75.7% of all the evaluations of social sustainability to consider in the development of a public civil infrastructure.

According to the order of relevance of each criterion in the life cycle, the experts identified the contribution of an infrastructure's design stage over most of the criteria that incorporate the categories "Stakeholder Participation" and "External Local Population". Similarly, the construction stage influences the criteria associated with "Internal Human Resources" and "Macro-Social Action" of "Socio-Environmental Activities"; operation puts at risk the "Macro-Social Action" of "Socio-Economic Activities" and demolition is significant in the categories "Stakeholder Participation" and "Internal Human Resources". The degree of importance of the social sustainability criteria is explained on the basis of the configuration of 16 groups of an infrastructure's characteristics, which represent agents of change affecting social sustainability criteria.

Although finding are limited to Chile and public infrastructure, whose functioning dynamic, public-private interaction, diversity of community end users and other orientations affect particularly the experts' responses to the study questions. The results may contribute to future studies, where the criteria are assessed, indicators specified, incidence factors deepened or methodological applications established to evaluate social sustainability in the development of public civil infrastructure in their beginning stage. Generally, the results of this study illustrate the opportunity to emphasize certain social sustainability criteria in order to intervene in an infrastructure's characteristics so as to guide their impact and objectify their measurement in specific study areas.

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Table 1: Evolutionary sample of studies that integrate at least 40% coverage of social impacts

	LITERATURE	Human Capital			Community					Productive Capital			Social Capital	Institutional Capital		Socioeconomic System		Company Product	Company - Labor Practices			
		Basic needs (food and clothing)	Education	Health care systems	Perceptions of the community	Esthetics and degradation	Security in the surroundings	Identity and social cohesion	Cultural capital	Private property	Impact on mobility	Infrastructures services, sports and recreation	Stakeholders' participation	Capacity of public administration work	Transparency and Integrity	General economic systems (Region / Country)	Job opportunities and / or stability	Product development and performance, compatible with human activity	Training of Human Resources	Occupational health and safety	Labor Practices	% Coverage of the impact
Conceptualizing the social aspect	Armour (1990)				x	x	x	X	x		x	x				x						**40**
	Hill and Bowen (1997)	x	x					X	x							x		x	x	x		**40**
	Vanclay (1999)			x	x	x	x	X	x	x	x	x	x		x	x				x		**65**
	Vanclay (2002)			x	x	x	x	X	x	x	x	x		x	x	x	x			x	x	**75**
	Labuschagne (2005)		x	x	x	x	x	X	x	x	x	x	x			x	x		x	x	x	**80**
	Wang (2004)	x	x	x				X	x									x	x	x		**40**
	Griffiths et al. (2011)			x	x	x	x	X	x	x	x	x	x			x		x		x		**65**
	Vallance (2011)	x						X	x			x	x	x	x		x					**40**
	Valdes and Klotz (2013)		x	x	x	x		X	x		x	x	x				x	x	x	x		**65**
References and methodological applications	Spangenberg (2002)	x	x	x							x	x	x		x	x	x			x	x	**55**
	Egre and Seneca (2003)			x				x	x	x	x				x	x	x				x	**45**
	Azapagic (2004)	x	x	x				x	x				x		x		x	x	x	x	x	**60**
	Burdge (2004)			x			x	x	x			x	x			x	x				x	**45**
	Gilchrist and Allouche (2005)			x	x	x				x	x	x				x				x		**40**
	Ugwu (2006 a and b)			x	x	x	x	x	x		x	x	x				x			x		**55**
	Labuschagne (2006)		x	x	x	x	x	x	x	x	x	x	x			x	x		x	x	x	**80**
	Ugwu and Haupt (2007)			x	x	x		x	x		x							x		x		**40**
	Lockie (2009)						x	x	x	x	x	x	x	x		x	x					**50**
	Koo et al. (2008)			x	x	x	x		x		x	x								x		**40**
	Koo et al. (2009)			x	x	x	x		x		x	x								x		**40**
	Fernandez-Sanchez and Rodriguez-Lopez (2010)			x		x	x	x	x		x		x		x			x		x		**50**
Policy recommendations for evaluation	ICPGSIA (1994)		x	x	x		x		x			x	x		x	x	x			x	x	**60**
	DGMA (2000a,b)		x	x		X			x		x	x				x	x			x		**45**
	ICPGSIA (2003)		x	x	x		x	x	x			x	x		x	x	x			x	x	**65**
	Indicators of sustainable development (2007)	x	x	x			x				x	x			x		x					**40**
	ISO 26000 (2010)			x				x	x	x	x	x	x		x		x	x	x	x	x	**70**
	GRI (2013)	x	x	x				x	x				x		x		x	x	x	x	x	**60**

Table 2: Formulation of coefficients for panel self-evaluation

COEFFICIENT	FORMULA	EXPLANATION
Knowledge (K_c)	$V \times 0.1 = K_c$	V is the self-assessment of the potential expert on a scale of 1-10 (0 means no specific knowledge of the subject, whereas 1 displays specific knowledge of the subject)
Argument (K_a)	$0{,}2 + \sum_{i=1}^{2} A_i = K_a$	A_1: Theoretical analysis (0.3 if high; 0.2 if medium; 0.1 if low) A_2: Experience in the field (0.5 if high; 0.4 if medium; 0.2 if low)
Competence (K)	$\frac{(K_c + K_a)}{2} = K$	• If $0.8 < K \leq 1.0$, then K is high. • If $0.5 < K \leq 0.8$, then K is medium • If $K \leq 0.5$, then K is low

Table 3: Characterization of the expert panel

Requirements	% Full expert panel	Profile 1 (62.5%)	Profile 2 (37.5%)
A	45.8%	20.8%	25.0%
B	66.7%	29.2%	37.5%
C	33.3%	12.5%	16.7%
D	[5-8] = 16.7%	12.5%	4.2%
	[9-12] = 37.5%	16.7%	20.8%
	[13-16] = 16.7%	8.3%	8.3%
	[>17] = 29.2%	25.0%	4.2%
E	70.8%	45.8%	25.0%
F	BSc = 33.3%	25.0%	8.3%
	MSc = 41.7%	25.0%	16.7%
	PhD = 25.0%	12.5%	12.5%
G	62.5%	50.0%	12.5%

Notes:
A: Primary or secondary author of at least 3 peer-reviewed journal articles.
B: Invited to speak at a conference
C: Member or chair of a nationally recognized committee (Chilean Network Executive Committee LCA; Foundation of Overcoming Poverty; Executive Committee of the Network for Research in Psychology, Economics and Consumer –Chile; Climate Knowledge and Innovation Community Association; Regional Roads Department - Ministry of Public Works – Chile)
D: At least 5 years of professional expertise
E: Faculty member at an accredited institution of higher learning
F: Advanced degree in the field of civil engineering or other related fields (minimum BS)
G: Professional registration (Association of Civil Constructors; Association of Civil Engineering; Association of Architects)
Profile 1: Experience and training in the area of public civil infrastructure
Profile 2: Experience and training in the area of social-environmental issues

Table 4: Competence coefficients of the expert panel

#	Coefficient of knowledge (K_b)	Coefficient of argument (K_a)	Coefficient of competence (K)
1	0.7	0.9	0.80
2	0.8	0.9	0.85
3	0.8	0.8	0.80
4	0.9	1.0	0.95
5	0.8	1.0	0.90
6	0.7	1.0	0.85
7	0.9	1.0	0.95
8	0.8	1.0	0.90
9	0.8	1.0	0.90
10	0.8	0.8	0.80
11	0.7	0.9	0.80
12	0.7	1.0	0.85
13	0.8	1.0	0.90
14	0.8	0.9	0.85
15	0.7	1.0	0.85
16	0.7	1.0	0.85
17	0.7	0.9	0.80
18	0.8	0.9	0.85
19	0.8	0.9	0.85
20	0.7	1.0	0.85
21	0.9	1.0	0.95
22	0.9	1.0	0.95
23	0.9	0.9	0.90
24	0.7	0.9	0.80

Table 5: Agreement and importance of the social sustainability criteria at the life cycle stages

				Agreement reached at ROUND 3		General order of relevance (1^{st} to 4^{th})				Average degree of relevance profile 1 (Likert 1 – 5)				Average degree of relevance profile 2 (Likert 1 – 5)			
Categories	Macro criteria	Items	Criteria contributing to social sustainability	Kendall's W	Asymptotic Significance	Design	Construction	Operation	Demolition	Design	Construction	Operation	Demolition	Design	Construction	Operation	Demolition
INTERNAL HUMAN RESOURCES	Job stability	1.1	Job opportunities	0.927	0.000		1.5	1.7	3.0		4.80	4.51	2.87		4.44	3.92	2.78
		1.2	Job benefits (e.g. remunerations, salary stability, social security, bonuses)	0.928	0.000		2.8	2.6	2.0		3.07	3.18	3.73		2.89	2.91	3.44
	Work Health and Safety	1.3	Health and safety practices to protect workers	0.560	0.000	3.5	1.8	2.4	1.9	2.91	4.93	4.20	5.00	2.85	5.00	4.11	4.78
		1.4	Occurrence of accidents and incidents	0.969	0.000		1.5	3.0	1.6		4.93	3.53	4.93		5.00	3.56	4.89
	Training and self-development	1.5	Training, further education of personnel and career development	0.914	0.000		1.5	1.6	2.9		4.60	4.67	3.47		5.00	4.56	3.00
		1.6	Innovation and research	0.266	0.000	1.7	2.7	2.6	3.0	4.33	3.87	3.60	3.73	4.44	3.56	3.89	3.44
	Employability practices	1.7	Disciplinary practices of contracting party	0.927	0.000		1.3	2.9	1.8		4.80	3.20	4.40		4,56	3.11	4.22
		1.8	Conditions of labor contract	0.922	0.000		1.7	2.8	1.5		4.73	3.40	4.73		4,44	3.56	4.67
		1.9	Equity (e.g. gender, social condition, race)	0.307	0.000			1.6	2.8			2.60	1.00			2.67	1.44
		1.10	Work-related sources (Child labor and others)	--	--												
	Work climate or proposed by experts	1.11	Personal satisfaction	0.869	0.000		2.5	1.3	2.3		3.13	4.20	3.40		3.11	4.33	3.11
		1.12	Workers' self-care and socialization conditions	0.854	0.000		2.1	1.6	2.3		4.00	4.47	3.87		3.89	4.22	3.67
		1.13	Workforce's awareness of sustainability	0.846	0.000	1.3	3.3	1.9	3.5	4.47	2.80	3.87	2.60	4.44	2.44	3.78	2.33
		1.14	Consideration of employees' sociocultural-religious aspects	--	--			1.0				3.47				3.56	
		1.15	Leadership conditions	0.227	0.001	3.0	2.3	2.1	2.6	3.27	3.73	3.80	3.60	3.22	3.44	3.78	3.33
EXTERNAL LOCAL POPULATION	Human capital	2.1	People's health	0.826	0.000	1.8		1.9	2.3	4.73		4.73	4.40	4.89		4.78	4.56
		2.2	People's education	0.934	0.000	1.5		2.5		3.20		2.57		3.33		2.22	
	Productive capital	2.3	Private property - dwellings	0.922	0.000	1.4	1.6	3.5	1.9	4.53	3.91	2.41	3.87	4.33	4.56	2.33	4.01
		2.4	Sanitary, electrical. telecommunications and other services	0.789	0.000	1.9	3.9	1.6	2.6	4.27	2.60	4.60	3.80	4.56	2.67	4.67	4.00
		2.5	Mobility infrastructure (Roads and transportation)	0.399	0.000	1.9	3.5	2.6	2.1	4.53	3.40	3.87	4.49	4.44	3.33	4.11	4.22
		2.6	Operability and development of public institutions.	0.785	0.000	2.0	1.4	2.9	1.7	3.70	4.55	2.45	3.89	3.44	4.23	2.75	4.40
	Community Capital	2.7	Stimuli for the senses (scents. noises. visual. vibrations)	0.889	0.000	1.4	3.3	1.8	3.6	5.00	3.60	4.80	3.33	4.89	3.56	4.44	3.22
		2.8	Safety	0.760	0.000	3.9	1.8	2.5	1.8	2.73	4.67	4.00	4.67	2.67	4.67	4.22	4.67
		2.9	Local economic benefits	0.921	0.000		1.9	1.2	2.9		3.87	4.53	2.60		3.89	4.44	2.78
		2.10	Material cultural property (e.g. heritage)	0.811	0.000	1.2	2.0	3.7	3.1	4.60	3.80	2.47	2.93	4.78	4.00	2.11	3.11
		2.11	Influence or generation in the development of social pathologies	--	--	1.0				4.33				4.67			
		2.12	Communal cohesion and identity	0.906	0.000	1.4		1.6		4.73		4.27		4.44		4.56	
MACRO-SOCIAL ACTIVITIES	Socioecon. activities	3.1	Socioeconomic benefits at Regional – National leve	0.976	0.000		2.0	1.0			3.27	4.73			3.78	5.00	
		3.2	Social marketing opportunities at Regional – National level	0.974	0.000		2.0	1.0			3.53	4.73			3.67	4.78	
	Socioenviron. activities	3.3	Socioenvironmental auditing and monitoring of projects	0.498	0.000	2.3	1.6	3.6	2.5	4.13	4.60	3.13	3.93	4.11	4.56	3.22	4.11
		3.4	Compliance with execution of environmental commitments	0.875	0.000		1.3	2.8	2.0		4.60	3.33	4.07		4.56	3.44	4.11
		3.5	Influence on legislation	0.626	0.000		1.9	1.5			2.07	2.33			2.00	2.33	
PARTICIPATION OF STAKEHOLDERS	Provision of information	5.1	Provision of information through collective audiences	0.933	0.000	1.2	2.9		2.0	5.00	3.33		4.27	4.89	3.44		4.44
		5.2	Provision of information through selective audiences	0.640	0.000	1.9	2.2	3.9	2.1	4.80	4.40	3.27	4.65	4.44	4.67	3.22	4.35
	Infl. of participants	5.3	Consideration of actors' opinions regarding project development	0.888	0.000	1.2	3.2	3.7	1.9	4.93	3.13	2.60	4.33	5.00	3.44	2.89	4.22
		5.4	Empowerment (Involvement) of the actors	0.407	0.000	1.5	2.6	3.1	2.8	4.87	4.27	3.40	4.13	5.00	4.11	3.33	4.00

Note: [grey cell] Criteria rejected by the experts in the indicated life cycle stage

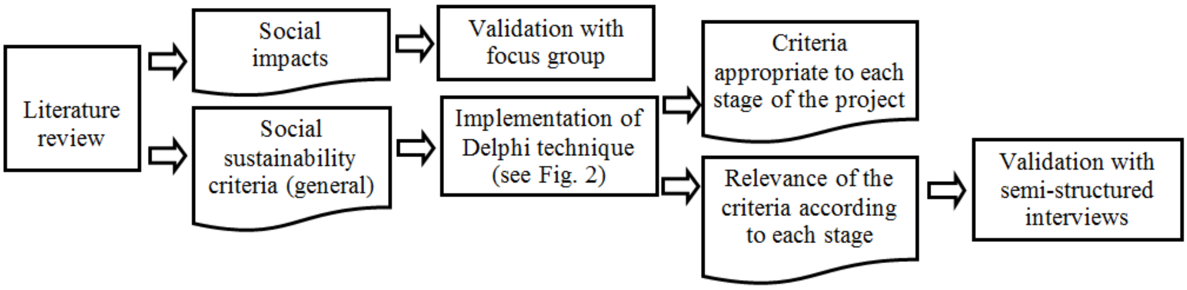

Figure 1. Research process

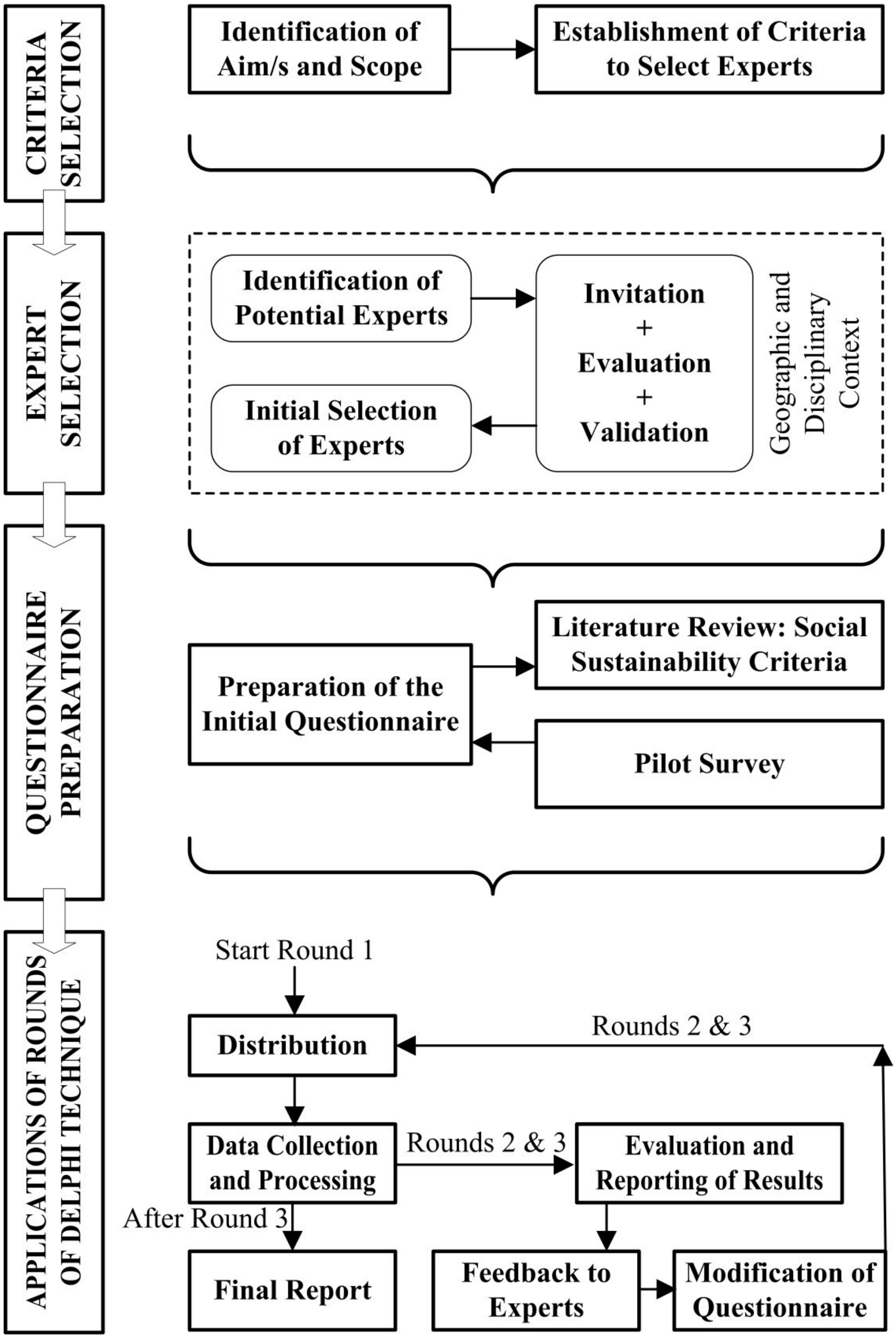

Figure 2. Steps in the Delphi method