METHOD FOR ESTIMATING THE SOCIAL SUSTAINABILITY OF INFRASTRUCTURE PROJECTS

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ABSTRACT

Nowadays, sustainability assessments tend to focus on the biophysical and economic considerations of the built environment. Social facets are generally underestimated when investment in infrastructure projects is appraised. This paper proposes a method to estimate the contribution of infrastructure projects to social sustainability. This method takes into account the interactions of an infrastructure with its environment in terms of the potential for short and long-term social improvement. The method is structured in five stages: (1) social improvement criteria and goals to be taken into account are identified and weighed; (2) an exploratory study is conducted to determine transfer functions; (3) each criterion is homogenized through value functions; (4) the short and long-term social improvement indices are established; and finally, (5) social improvement indices are contrasted to identify the socially selected alternatives and to assign an order of priority. The method was implemented in six alternatives for road infrastructure improvement. The results of the analysis show that the method can distinguish the contribution to social sustainability of different infrastructure projects and location contexts, according to early benefits and potential long-term equitable improvement. This method can be applied prior to the implementation of a project and can complement environmental and economic sustainability assessments.

KEYWORDS: Social Contribution, Social Improvement, Infrastructure, Method, Social Sustainability

1. INTRODUCTION

The sustainable contribution of an infrastructure has to be measured within its own context. Social facets are more influenced by context than environmental or economic ones. These social facets have to be considered in the short and long term and must be properly defined for each project investment (Valdés-Vásquez and Klotz 2013).

Infrastructure projects promote economic well-being, complement many social interventions and facilitate participation in sociopolitical processes (Asomani Boateng et al. 2015). An infrastructure by itself, however, may have a reduced impact on society (Gannon and Liu 1997, Van de Walle 2009). The assessment of the social impact that an infrastructure has on a region has been under-researched to date. Since the mid-20th century, monetization-based methods have been widely used to evaluate infrastructure projects (Mostafa and El-Gohary 2014). Nevertheless, some authors have introduced environmental aspects into this evaluation (Torres-Machi et al. 2014, 2015, Yepes et al. 2015a), with sustainability reaching beyond the analysis of monetary efficiency (Colantonio 2011). Mostafa and El-Gohary (2014) emphasize the limitations of these methods compared to equitable distribution and the assessment of non-economic aspects; they also add the assumption that investment is inadequate if the benefits do not exceed the costs.

In the last decade, methods have been proposed to assess the sustainability of infrastructure projects, aiming to make sustainable development measurable. In Spain, the “Integrated Value Model for Sustainability Assessment” (MIVES in Spanish) can consider the social facet, even though it has been extensively used for the assessment of environmental and economic criteria (De la Cruz et al. 2015). The social facet can be assessed with a value function proportional to the average satisfaction of the experts. There is no evidence of a simultaneous treatment of different contexts considering the social facet. Nor is there a clear approach that maximizes the improvement of social need in the context of an infrastructure project.

The “Sustainability Appraisal in Infrastructure Projects” (SUSAIP) has been applied in the Chinese construction industry for bridges and viaducts (Ugwu et al. 2006a, b). This method assesses different types of designs considering their geographic context. Thirty percent of its indicators consider the social facet. However, the method assumes the same conditions for different contexts. Furthermore, there is only one decision-maker in the method.

The “Technical Sustainability Index” (TSI) has been applied in Canada for electrification infrastructures (Dasgupta and Tam 2005). This method takes into consideration a set of indicators applied to different stages of the assessment. Within the environmental indicators, the method deals with human indicators such as health, wealth and politics. Socially, the method is focused on long-term efficiency in a single context; short-term impact is not considered.

2. POINT OF DEPARTURE

Colantonio (2011) establishes social sustainability as a condition and a process that improves a community’s quality of life. Asomani and Boateng (2015) identify states of social development according to the extent of improvement after an intervention. Other authors associate social sustainability with the adequate distribution of well-being in the present and future (Valdes-Vasquez and Klotz 2013, Mostafa and El-Gohary 2014). Indeed, the social impact of infrastructure depends on its life cycle (design, construction, operation and disposal) (Sierra et al. 2016). Based on these assumptions, this study allows for the current (short-term) and future (long-term) states with respect to an infrastructure project.

In the short term, Valdes-Vasquez and Klotz (2013) consider that the context of the place, the user and the commitment and identification of the key stakeholders are aspects to take into account in the design and planning of an infrastructure project; in addition, a large part of the social impact depends on the pre-existing conditions or immediately added interventions (Van de Walle 2009). Short-term social improvement does not necessarily imply adequate distribution of the social benefits; in fact, in some cases it harms sectors in social need (Foth et al. 2013). Therefore, distribution mechanisms that include the most vulnerable population must be ensured (Mostafa and El-Gohary 2014) so those abilities are developed in conditions of social need. This is a process with long-term results.

An infrastructure project contributes to sustainability in the short and long term, which can be measured using social improvement criteria and goals, respectively. The criteria are requirements to an intervention that must be fulfilled to obtain a sustainability standard (Pavlovskaia 2013). Most of the social criteria cited from the 1990s have been addressed by Labuschange et al. (2005). On the other hand, the social improvement goals for a zone are more appropriate for a long-term approach. Specifically, the orientation of a social improvement goal is related to types of social indicators (Fulford et al. 2015); a social indicator is a measurement to monitor society's progress in terms of improvements in well-being over time, or the change in society with respect to evolving development goals (Noll 2013).

Therefore, according to what was set out in the previous points, the knowledge gap in the social sustainability assessment of infrastructure presents two aspects: (1) the social contribution in terms of how infrastructure interacts with its context (Gannon and Liu 1997, Van de Walle 2009, Asomani-Boateng et al. 2015), and (2) the potential benefit distribution effects on a long-term basis balanced with its short-term contribution (Colantonio 2011, Foth et al. 2013, Sierra et al 2016). These ideas are the point of departure for this study.

3. OBJECTIVES OF THE RESEARCH

This article proposes a general method to assess the contribution of infrastructure projects to social sustainability in different geographic contexts simultaneously. This purpose is achieved with three specific goals that determine: (A) the estimation of social improvement produced by the infrastructure project in the short term; (B) the estimation of social improvement produced by the infrastructure project in the long term (or social development); and (C), the joint assessment of social improvement produced by the infrastructure project in the short and long term, prioritizing the different alternatives.

In order to accomplish these goals, this article is structured as follows: The first section contains the proposed method, based on multicriterion and multi-objective techniques, the Delphi method and systems theory. Next, the proposal is applied to a specific case so the reader can appreciate its practical implementation. Then the results are discussed. Finally, the contributions, recommendations, limitations and future lines of research are presented.

4. PROPOSED METHOD

In order to fulfill the goals of this research, a general method is presented to evaluate an infrastructure's contribution to social sustainability. Its use supports the decision-making process in the early formulation phases of the project. This method is structured in three groups of processes, according to the three aforementioned specific goals. For each group of processes, the outcome is: (A) an index of short-term social improvement (STSI); (B) an index of long-term social improvement (LTSI); and (C) the multi-objective prioritization of different alternatives of an infrastructure investment. STSI identifies an infrastructure's contribution in interaction with the present context. In this study, the short term considers the social effects of infrastructure planning, design and construction for approximately three years from the start of the operation. On the other hand, in the long term, the distribution impact of the benefit considers the zones in social need. The long term considers the social effects on the type of tenure and preservation of the infrastructure. Once the social improvement for the different alternatives has been identified, these can then be prioritized according to their contribution to social sustainability.

Fig. 1 illustrates the processes that intervene in the assessment method. In accordance with the previously established objectives, the processes labeled “A” intervene in social improvement in the short term. Comparably, the processes labeled “B” determine social improvement in the long term. Finally, processes “C” determine the prioritized solution of socially sustainable infrastructure projects and their stability. The dotted line shows the flow of information as well as the scoring steps of criteria and social goals. In the following sub-sections, each of the processes that compose the proposed method is explained according to the layout shown on the left side of Fig. 1.

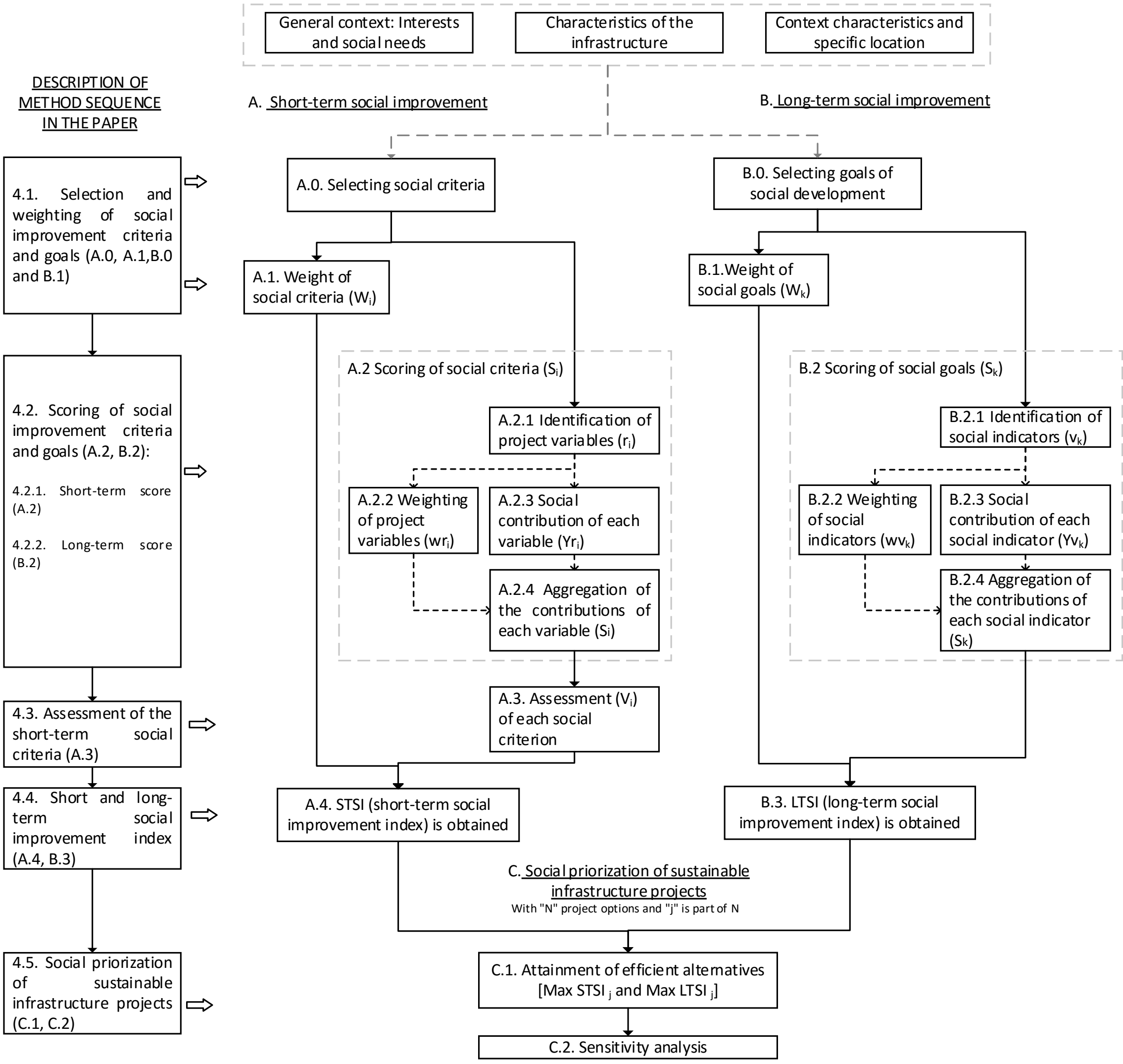


Fig. 1. Proposed method.

4.1. Selection and weighting of social criteria and goals (A0, A1, B0, B1)

The specific criteria and goals of social improvement are selected from a pre-established set of criteria (Labuschagne et al. 2005) and national goals (UN 2015). The pre-selection takes into account: (1) the general interests for social improvement in the short and long term, and (2) incidence of characteristics of the type of public infrastructure being studied. Experts are needed to disclose their conformity or nonconformity with every aspect of the sample of criteria and goals, and may consider others to be relevant.

At least eight experts are required to obtain a consensus applying the Delphi method (Hallowell and Gambatese 2010), a qualitative structured communication technique developed as an interactive systematic method of prediction based on a panel of experts (Cortés et al. 2012, Alshubbak et al. 2015). Generally, the expert's profile must fulfill a minimum of four requirements from a list of 10 proposed by Hallowell and Gambatese (2010) in order to guarantee the rigor of the method. These include university degree, membership in professional associations, minimum of professional experience, authorship of papers or book chapters, and so on. In particular, for the short term, experience in public infrastructure projects as well as specific knowledge of the region under study are desirable. Conversely, for the long term, institutional representation and sociohistorical knowledge of the context can be required. Additionally, an interdisciplinary expert panel configuration is also necessary (Munda 2006) as a panel of experts should represent the interests of the stakeholders involved in the region.

Later, the experts are asked to provide a solution to the following question:

A.1. Based on the greater contribution to short-term (or long-term) social improvement, compare the degree of importance between the different social criteria (or social improvement goals) for an infrastructure.

The experts are asked to indicate on a pairwise-comparison questionnaire the importance of a criterion (or social improvement goal) compared to another by applying an analytic hierarchy process (AHP). The AHP is a technique that determines the weight of different aspects through the dual and consistent comparison of their importance on a scale from "1", equal importance, to "9", extremely important (Saaty 1987, Ahmadvand et al. 2011). Table 1 shows an excerpt from the questionnaire prepared for the experts' responses. Thus, the criteria and goals are processed to obtain their relative weights. The process is iterative until a consensus is obtained or a number of rounds not less than three is reached (Hallowell and Gambatese 2010). According to Fernández-Sánchez and Rodríguez-López (2010), those aspects that concentrate 80% of the greatest importance are suitable for a methodological process. The results contain selected criteria "i" (or improvement goal "k") and their relative weight. The relative weight of each criterion (or development goal) is normalized to the total weight of the selected criteria (or improvement goal). The new weights of the selected criteria or social improvement goals are called "Wi" or "W_k.", respectively.

Table 1: AHP questionnaire sample applied to the experts

Based on the greater contribution to short-term (or long-term) social improvement, compare the degree of importance between the different social criteria (or social improvement goals) for an infrastructure In each comparison to register only the preference of more importance. Use the scale of importance from 1 until 9 (*)				
Pre-selected criteria of short – term				
"Employment"		vs		"Property and habitability"
"Employment"		vs		"Safe environmental"
"Employment"		vs		"Communal cohesion and identity"
"Employment"		vs		"Citizen participation"
"Property and habitability"		vs		"Safe environmental"
…….		vs		……
"Communal cohesion and identity"		vs		"Citizen participation"
Pre-selected goals of long-term				
"Economy"		vs		"Health"
"Economy"		vs		"Education"
"Economy"		vs		"Innovation"
"Health"		vs		"Education"
…		vs		…
"Education"		vs		"Innovation"

(*) Note:
1: The same importance; 3: Moderate importance; 5: Greater importance; 7: Very great importance; 9: Extreme importance; Values 2,4,6 and 8 can be used for intermediate points

4.2. Scoring of social improvement criteria and goals (A.2, B.2)

For each social improvement criterion and goal, a score is given as the interrelation between the project characteristics and the social context. Social contexts can be viewed from a systemic approach. A social system can be considered as a set of dynamic processes adaptable to disruptions (Luhmann 1998, Dominguez-Gomez 2016). In this sense, social interrelation is a complex system that can be understood from its internal or external description (Xing et al. 2013). In general terms, an internal description structures the behavior of the system in terms of its variables and interdependence. Alternatively, an external description is considered a black box, displaying the functional relations of the system's inputs and outputs. These functional relations translate into transfer functions that explain how the inputs are processed to produce the outputs (Le Moige 1990). In this field, the transfer functions are associated with a soft systems methodological and historical experience given by stakeholders for a specific context. In this vein, a complex system must be understood in relation to its context, which has an input gathering process (Xing et al. 2013). Based on a systems approach, the following paragraphs describe the process to determine the long and short-term scores.

4.2.1. Short-term score (A.2)

The scoring mechanism of a criterion depends on the contribution of the project within the context intervals, measured on a scale of 0 to 100. Assumptions to determine the score of each criterion are expressed in the following lines. In the short-term, the score values (S_i^{ST}) for an infrastructure's contribution to each social criterion (i) could be assumed to be in a state of certainty. Therefore, the input of each social criterion is conditioned to the available and verifiable information. The formulation of "S_i^{ST}" takes four aspects into account: (1) the infrastructure variables "r" and their value "X_{ir}" that affect each social criterion “i” according to the infrastructure type and life cycle stage; (2) the weight the variables have in a social criterion “ω_{ir}”; (3) the vector of conditioning factors “C_r” regardless of the project and related to the context that impacts on the contribution of each variable “r”; and finally, (4) the transfer function “$f_r(X_r, C_r)$” that explains the response “Y_r^{ST}” of an idle social system to the drive for development caused by the infrastructure for each variable “r”. Fig. 2 illustrates the systemic process for determining a score for the social contribution of an infrastructure project. Eqs. [1] and [2] represent the response of the transfer functions (Y_{ir}^{ST}) and the score (S_i^{ST}) of each social criterion with respect to an infrastructure project.

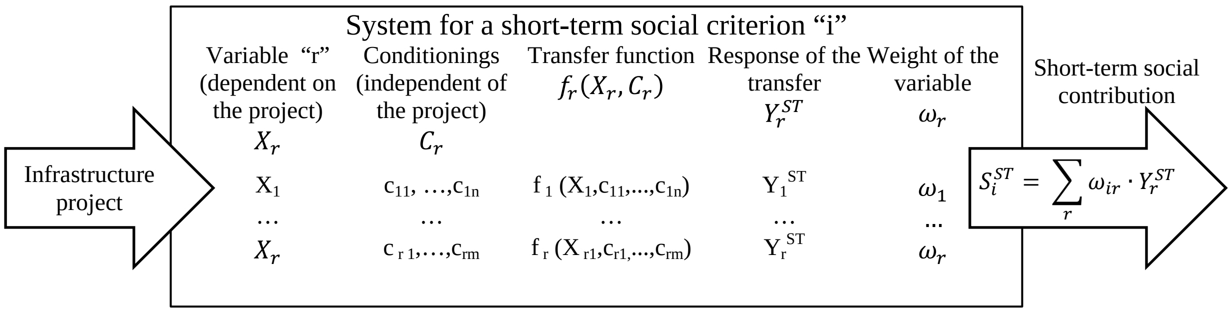


Figure 2: Intervening elements for scoring a social criterion in the short term.

$$Y_{ir}^{ST} = f_{ir}(X_{ir}, C_{ir}) \qquad [1]$$

$$S_i^{ST} = \sum_r \omega_{ir} \cdot Y_{ir}^{ST} \;\; ; \;\; being \;\; \sum_{r=1}^{n} \omega_{ir} = 1 \quad and \quad S_i^{ST} \in [0 - 100] \qquad [2]$$

Each short-term transfer function “$f_{ir}(X_{ir}, C_{ir})$” is determined according to the type of infrastructure in its relation to the social environment. An example of transfer function with quantitative variables is shown in Eq. [3]. In this function the value of each variable “X_{ir}” is measured according to the type of project. The performance range can be identified through the conditioning factors “$c_{ir\text{-}max}$” and “$c_{ir\text{-}min}$”. Variables such as hiring personnel, project deadlines or investment in safety and health could be modeled this way. Similarly, Alarcón et al. (2011) set out functions limited between maximum and minimum ranges to represent the contribution of buildings to economic and environmental sustainability.

$$f_{ir}(X_{ir}, c_{irmax}, c_{irmin}) = 100 \cdot \frac{[X_{ir} - c_{irmin}]}{[c_{irmax} - c_{irmin}]}; \;\; being \; c_{irmin} \le X_{ir} \le c_{irmax} \qquad [3]$$

In the case of qualitative variables or conditioning factors, the information “X_{ir}” or “c_{ir}” of each variable “r” can be defined according to the situation. For instance, the variable “safety during construction” could correspond to construction works alongside vehicular traffic and/or with direct access to main roads. The zonal conditioning factors can enhance or reduce the contribution of the infrastructure’s variables. For example, high local unemployment increases the impact of the variable “employment” on the infrastructure in the zone. In these cases a transfer function can be the interaction of the variables of infrastructure and conditioning factors. Each interaction is valued according to the distribution of 100 points per variable consistent with the level of influence. In each infrastructure type and location context, determination of the variables, their weights, conditioning factors and transfer functions are the result of an exploratory study. Fig. 3 shows a recommendation of techniques to use to perform this process. An expert consultation can be part of the process of exploratory research. Prior to any such consultation, however, a document review and field studies are recommended. In this regard, techniques are needed that provide greater reasoning (e.g. interviews and conceptual maps) and validation (e.g. surveys and Delphi method) of the variables, conditioning factors and their interaction.

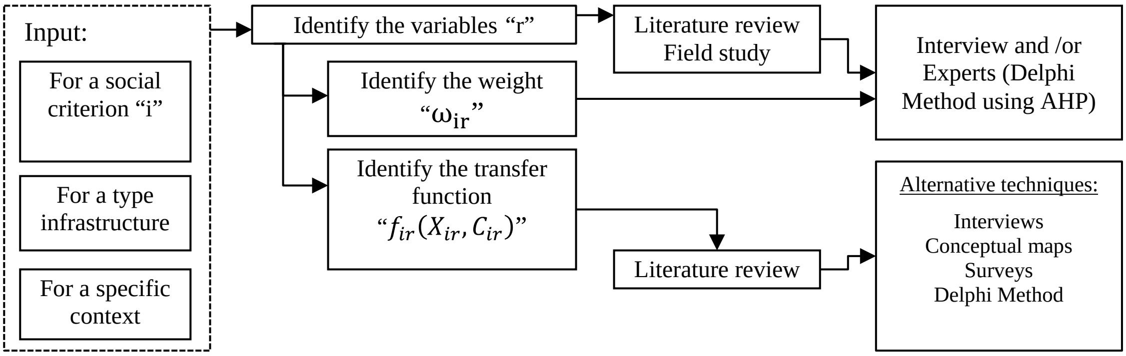


Figure 3: Determination of variables, weights and transfer functions.

4.2.2. Long-term score (B.2)

The score for each social improvement goal "k" in the long term (S_k^{LT}) depends on the ability of the project to satisfy social needs. Similarly, a systemic approach is illustrated in Fig. 4 to determine the score of the infrastructure long-term social improvement for a goal "k". In this case, the response of each transfer function depends on the improvement of each zonal indicator that characterizes a goal "k". In addition, an indicator must provide reliable information and represent the structural needs of the area. Given the uncertainty of this condition, field studies and expert consultations are recommended. Thus, the "S_k^{LT}" formulation takes five aspects into account: (1) the indicators "v" that represent each improvement goal and which have data available; (2) a vector of zonal conditioning factors "C_v" that characterize the present state of indicator "v" in the zone; (3) a vector of variables "Z" of the infrastructure that could affect the set of indicators; (4) the weight that the indicators have on a social improvement goal "ω_{kv}"; and finally, (5) the transfer function "$f_v(Z, C_v)$", which explains the response "Y_v^{LT}" in the long term of the drive to develop motivated by the infrastructure. Eqs. [4] and [5] represent the response of the transfer functions (Y_{kv}^{LT}) and the score (S_k^{LT}) of each social improvement goal with respect to an infrastructure project.

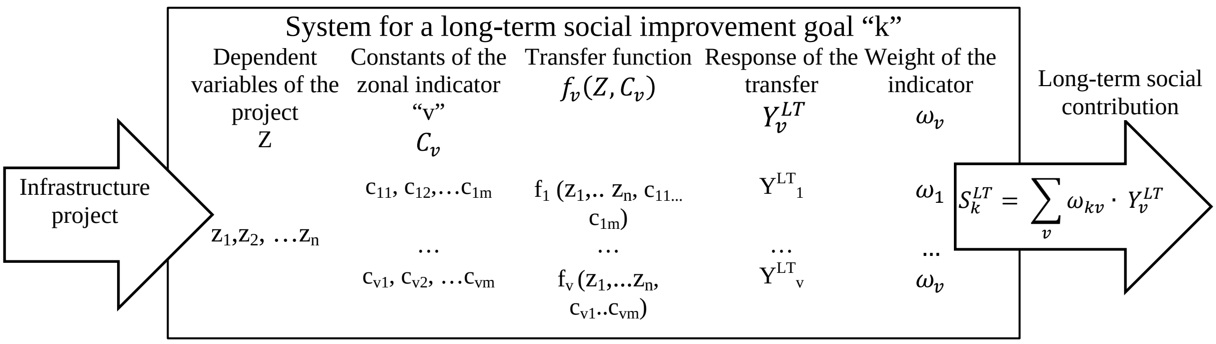


Figure 4: Intervening elements in the score contributing to a long-term social goal.

$$Y_v^{LT} = f_v(Z, C_v) \qquad [4]$$

$$S_k^{LT} = \sum_v \omega_{kv} \cdot Y_v^{LT} \; ; \; being \; \sum_{v=1}^{n} \omega_{kv} = 1 \; and \; S_k^{LT} \in [1-25] \qquad [5]$$

In this case, the transfer function "$f_{kv}(Z, C_{kv})$" promotes the right distribution of the infrastructure's benefits according to the zone's initial social conditions (Esteves and Vanclay 2009, Fulford et al.2015). For this, a systematic consultation with a panel of experts (equivalent to the panel in the B.1 process) is done until a consensus is reached. To do this, the panel is informed of the variables in project "Z" and the vector "C_v" of the current social indicators in the zone, their trend and position in the region. The process begins when the panel is asked to provide a solution to the following questions:

B.2.1. - According to the characteristics of the infrastructure project and on a scale of 1 (minimum benefit) to 5 (maximum benefit), identify the degree of long-term benefit that the project would generate for each social indicator.

B.2.2. - According to the current situation of the project location zone and on a graduating scale of 1 (minimum social need) to 5 (maximum social need), identify the degree of need in each project zone with respect to each social indicator.

If consensus cannot be reached, the experts are asked to reconsider their responses after feedback from the previous results. The response of the social transfer function (Y_v^{LT}) for each indicator "v" is the product of the degree of potential benefit from the infrastructure (B.2.1) and the degree of zonal need (B.2.2).

4.3. Assessment of the short-term social criteria (A.3)

The multi-attribute utility theory represents a structure of preferences by means of a function. Under a short-term approach in which a state of greater certainty is admitted, a value function is used (Mel et al. 2015). A generic value function is used to unify the scores (S_i^{ST}). This function is developed to estimate sustainability and has been applied to buildings (Alarcón et al. 2011) and to concrete structures (Gómez-Lopez et al. 2013). This function normalizes the tendencies of the criteria with demonstrated behavior and represents them through a unit of "value" (Gómez-Lopez 2013). This means that in concave functions that imply low social demand, high satisfaction is reached with few improvements. Convex functions implying high demand require large improvements in the criterion to achieve satisfaction. In a linear function the increase in satisfaction is constant with respect to the improvement. In addition, it is possible that the levels of demand for a criterion depend on the development in a region (Max-Neef 1995). Therefore, to promote the development of weak criteria, a strategic decision is to use concave curves. Convex curves are more appropriate for developed criteria where the desire is to obtain a high standard (Alarcón et al. 2011). Finally, Alarcón et al. (2011) recommend linear functions for decision making on criteria with no clear trend. Eq. [6] represents the generic value function, with V being the value of each short-term social criterion "i" and the parameter "S_i^{ST}" the score of each criterion "i". The parameters m_i, n_i, and A_i define the convex ($A_i \geq 2$, $m_i \leq 0.1$, $n_i \geq 45$), concave ($A_i \leq 0.75$, $m_i \geq 0.9$, $n_i \approx 100$), or linear form ($A_i \approx 1$, $m_i \approx 0$, $n_i \approx 15$) of the criterion (Manga 2005). "K_i" limits the result interval of the function of V = 0 (S_i^{ST} =0) to V =1 (S_i^{ST} =100) (Alarcón et al. 2011).

$$V_i = K_i \cdot \left[1 - e^{-m_i\left(\frac{S_i^{ST}}{n_i}\right)^{A_i}}\right] \qquad [6]$$

4.4. Short and long-term social improvement indices (A.5, B.4)

The short and long-term social improvement index is the result of the simple additive weighting of each criterion and social indicator. This technique provides an indicator equivalent to the weighted mean. The short-term social improvement (STSI) index varies on a scale from 0 to 1, and reflects the level of social contribution that an infrastructure project contributes to a context in the short term. The STSI index is obtained from the values "V_i" and normalized weights "Wi". Each normalized weight is obtained by dividing each criterion chosen using the Delphi method by the total sum of the weights. Eq. [7] illustrates the STSI index of an infrastructure project.

$$STSI = \sum_{i=1}^{n} W_i \cdot V_i \qquad [7]$$

Likewise, the long-term social improvement (LTSI) index varies on a scale from 1 to 25 and reflects the reinforcement potential of the long-term social needs in areas with the greatest need. The LTSI index is obtained from the values "S_k" and normalized weights "W_k". Eq. [8] shows the LTSI index of an infrastructure project.

$$LTSI = \sum_{k=1}^{n} W_k \cdot S_k^{LT} \qquad [8]$$

4.5. Socially sustainable solutions (C.1, C.2)

Infrastructure project alternatives "j" are selected according to the simultaneous evaluation of STSI and LTSI indices. Fig.5 shows the sequence of activities to identify the eligible projects.

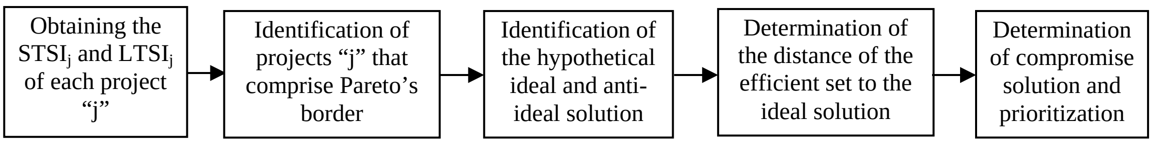


Figure 5: Sequence of activities to identify the eligible projects according to their contribution to social sustainability.

Charting "STSI vs. LTSI", the alternatives that comprise Pareto's border are identified. The efficient projects are those for which there is no other project alternative that improves one index without making the other worse (Garcia-Segura et al. 2015). In turn, the ideal solution is the best result of STSI and LTSI of the socially efficient set. Similarly, an anti-ideal solution corresponds to the worst result of STSI and LTSI. On this point, multi-objective compromise programming is used to reduce the efficient solutions. This subgroup of solutions is determined with respect to the shortest distance to an ideal solution. For two goals a compromise subgroup is limited by solutions with metric distances d_1 (Manhattan's distance) and d_∞ (Tchebychev's distance) (Yepes et al.

2015b). Eqs. [6] and [7] represent the mathematical model of the subgroup of compromise solutions for this model. In these, d_∞ is the maximum individual distance of each objective and d_1 is the orthogonal sum. Then, projects with the minimum Manhattan and Chebyshev distances are eligible candidates. The $STSI_j$ and $LTSI_j$ represent the values of the indices of each j^th^ project. The λ_1 , λ_2 are the weights of the improvement goals; the $STSI^*$ and $LTSI^*$ indices represent the ideal solution, and the $STSI_*$ and $LTSI_*$ the anti-ideal solutions for the short and long-term social improvement goals, respectively.

$$Min\ \ d_\infty\ ; \qquad d_{\infty j} = Max\left[\lambda_1 \cdot \left(\frac{STSI^* - STSI_j}{STSI^* - STSI_*}\right);\ \lambda_2 \cdot \left(\frac{LTSI^* - LTSI_j}{LTSI^* - LTSI_*}\right)\right] \qquad [6]$$

$$Min\ \ d_1\ ; \qquad d_{1j} = \lambda_1 \cdot \left(\frac{STSI^* - STSI_j}{STSI^* - STSI_*}\right) + \lambda_2 \cdot \left(\frac{LTSI^* - LTSI_j}{LTSI^* - LTSI_*}\right) \qquad [7]$$

A sensitivity analysis is proposed from a set of solutions. The sensitivity analysis identifies the effect on the assessment of social sustainability for each infrastructure after the possible variation of the input elements. This analysis consists of the iteration of regular and independent variations of each input variable, susceptible to uncertainty, keeping the rest constant (Mel et al. 2015). The variation of the input elements determines the stability intervals of the solution.

5. CASE STUDY

A case study is presented to illustrate the method and its practical application. This case study is an adaptation of the project "Revitalization of Local Economies through Public Infrastructure” implemented in El Salvador. The project is led by the United Nations Development Program (UNDP) and El Salvador’s Ministry of Public Works. The project aims to strengthen institutional capacities for planning and prioritizing public infrastructure. This objective takes into account the potential and integrated development of rural and intercity areas. Thus, a set of infrastructure projects in the national portfolio were analyzed by multisectoral experts and the research team. From this set, three contexts and two options of projects for rural and intercity roads were selected to illustrate the method. Key aspects and results of the application of the method are described in the following paragraphs.

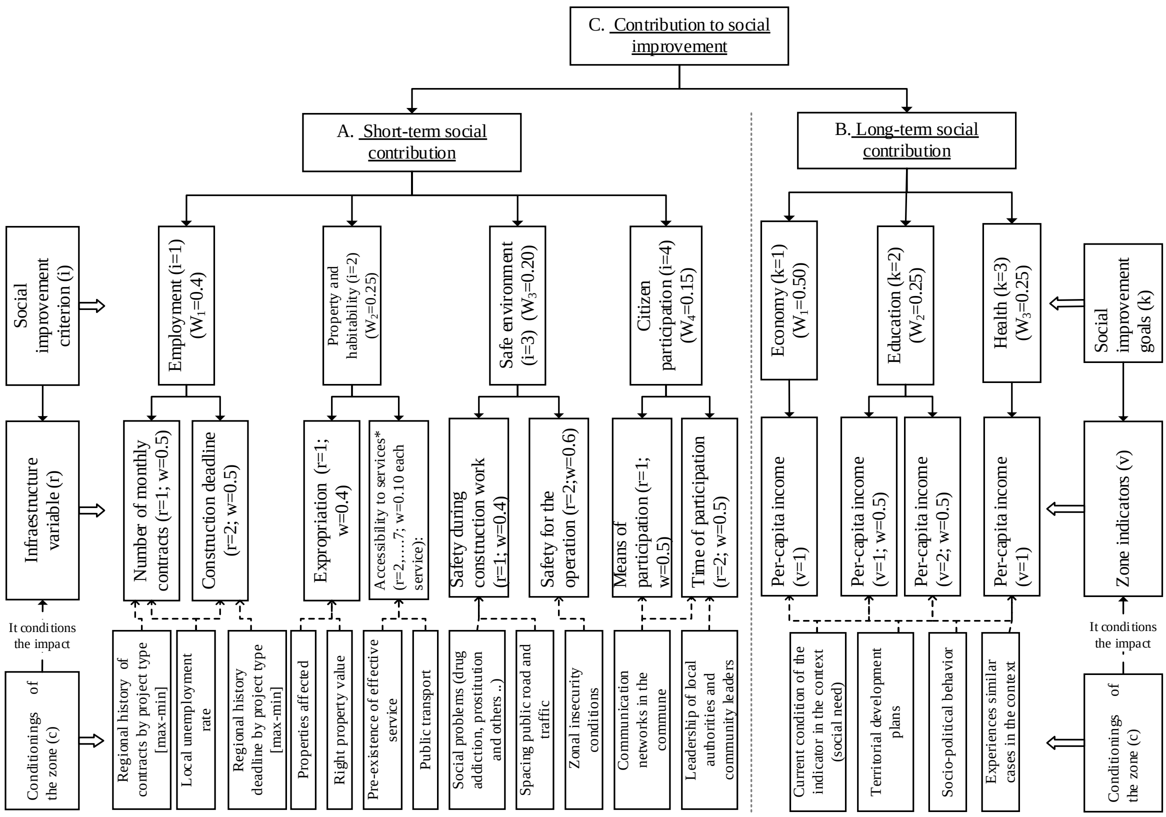
5.1. Social improvement criteria and goals

An expert panel was formed according to the requirements explained in the above sub-section 4.1. Table 2 specifies the characteristics of the set of experts who participated in this case study. Three rounds were needed to reach consensus. Criteria and goals (short and long term, respectively) that reached more than 80% of importance are shown in Fig. 6. Furthermore, Fig. 6 presents the variables of the infrastructure projects and their conditioning factors to illustrate the case study. These elements and their interactions stemmed from the review of similar projects in this context (literature review and field studies). A semi-structured interview with six experts concluded the exploratory study. Furthermore, the social indicators in the long term are also displayed in Fig. 6. For each social goal, a quality review of the data available for the context indicators was performed. The field studies and interviews also helped to align the social indicators most representative of a social goal. A proposal of indicators, variables, conditioning factors and their relationships was validated by the panel of experts during the first round.

Table 2: Characteristics of the expert panel (Case Study El Salvador)

Requirements		**Profile l** (15)	**Profile 2** (14)
A		26%	28%
B		30%	46%
C	1	--	7%
	2	27%	7%
	3	20%	--
	4	27%	36%
	5	13%	21%
	6	13%	7%
	7	--	14%
	8	--	14%
D	[5-15]	20%	7%
	[16-25]	33%	43%
	[26 or more]	47%	50%
E	BS	47%	29%
	MSc	46%	57%
	PhD	7%	14%
F	Social	20%	29%
	C.E. /Arq.	40%	29%
	Environmental	20%	14%
	Health	6%	7%
	Economy	13%	21%
G		53%	12.5%

Notes:
A: Author of peer-reviewed journal articles.
B: Invited to speak at a conference
C: Member of a nationally/regionally recognized committee or institution (1.Central government, 2 Technical departments MOP, 3. Social Development Departments, 4 Universities, 5 NGOs (UNDP, local foundations), 6 Public Health Institute, 7 Chamber of commerce and privates, 8 Regional delegate).
D: At least 5 years of professional expertise
E: Advanced degree in the field of civil engineering, CEM, or other related fields (minimum BS)
F: Knowledge Area
G: Professional registration
Profile 1: Members of the expert panel to evaluate short-term
Profile 2: Members of the expert panel to evaluate long-term



(*) Servicies as: Primary education center (r=2), Secondary education center (r=3), Health center (r=4), Hospital (r=5), Commerce (r=6), Police (r=7)

Fig. 6: Decision-making structure of case study

5.2. Description of the alternatives of infrastructure projects

Currently, El Salvador is a developing country, after suffering through a 12-year Civil War (1980-1992). According to the DIGESTYC (2014), its poverty rate is 31.85%, its per-capita income is US 1742 per annum and its human development index is 0.67, one of the lowest in Central America. In this macro-context the public administration agency must prioritize the infrastructure alternatives. To do this, it wants to consider the contribution to social sustainability. The case study focuses on the analysis of six alternatives comprised for the combination of two options of road projects alternatively applied in three rural sectors of the country. The two road project options are technically applicable to all the identified sectors. Option A is a rehabilitation that includes works of transverse and longitudinal drainage, treatment of critical points and maintenance of a gravel road. In this case, the speed limit does not exceed 40 km/h. Option B involves an improvement and adds road widening work to a standard of 7 m and hydraulic concrete paving. As needed, this solution also incorporates the treatment of critical points and improvement of the drainage system. In this case, the speed limit does not exceed 90 km/h.

The general geographical context of each study zone is presented in Fig. 7 and is described next:

- Zone 1: It presents highly deteriorated concrete and stone pavement. The road connects the seasonally isolated local area with a highly populated city. The project benefits 1,500 inhabitants. The annual mean daily traffic on the road is 800 vehicles. The intervention length is 7 km. The local economy is based on the agriculture industry.

- Zone 2: It presents a rural road which connects five local areas. The road benefits 2,680 inhabitants. This is a gravel road which varies in width; it has difficult accessibility and a high accident rate in winter. The mean annual daily traffic is 500 vehicles and the intervention length is 15 km. The local economy is based on tourism, mainly in mountainous areas. The zone presents unexploited historic-cultural conditions.
- Zone 3: It presents an intercity road which connects two local areas and one city. The zone has untapped port facilities. However, there are political and civic pressures for its early regularization and exploitation. The road has a gravel loose pebbles and a deteriorated drainage system. The project benefits 600 inhabitants. The annual mean daily traffic is 300 vehicles and the intervention length is 7 km. The zone is located in a coastal sector and has poor tourism development. The local economy is based mainly on agriculture and fishing.

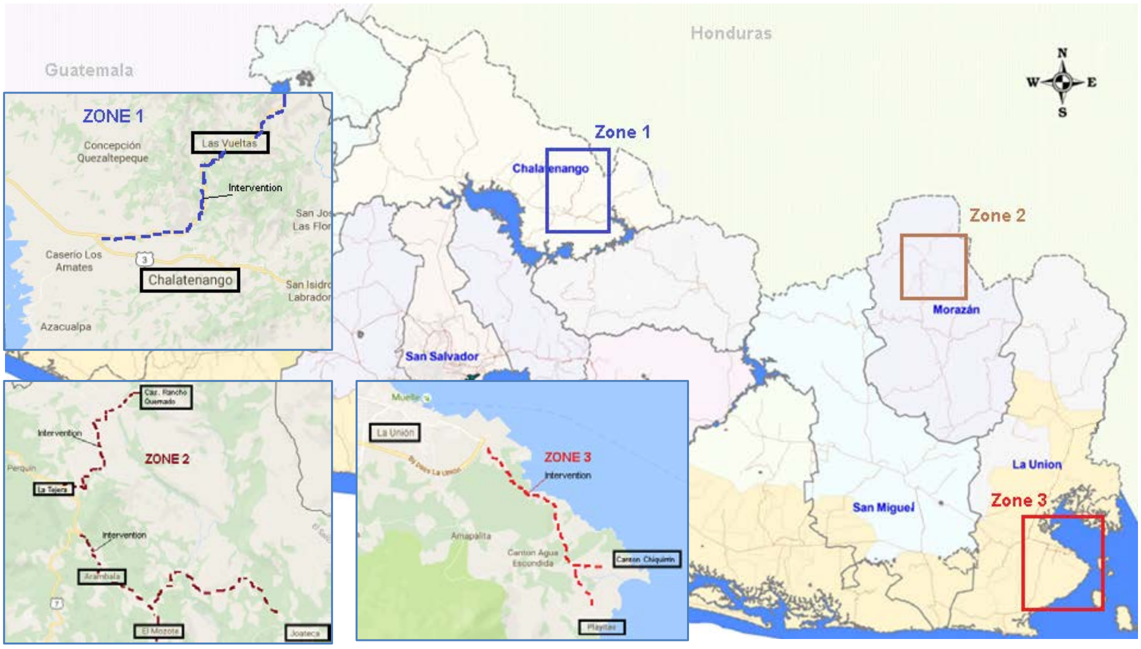


Fig. 7: Geographical location of assessment contexts.

Table 3 displays the main background used for the assessment of social improvement in the short term. Data were obtained from the review of projects, field studies, interviews with designers and statistical data (DIGESTYC 2014).

Table 3: Synthesis of the background of the alternatives for short-term evaluation.

Social improvement criterion (i), variables (r) and constants (c_{ir})	**Project versus zone**					
	A1	**B1**	**A2**	**B2**	**A3**	**B3**
Employment (i=1)						
Number of monthly contracts (r=1)	*60 contracts*	*30 contracts*	*70 contracts*	*45 contracts*	*50 contracts*	*35 contracts*
Regional history of contracts by project type [c_{111}-c_{112}]	*[18-80]*		*[18-80]*		*[18-80]*	
Construction deadline (r=2)	*3 months plus 12 months of*	*4 months*	*4 months plus 12 months of*	*6 months*	*3 months plus 12 months of*	*4 months*

Social improvement criterion (i), variables (r) and constants (c_{ir})	Project versus zone					
	A1	**B1**	**A2**	**B2**	**A3**	**B3**
	maintenance		*maintenance*		*maintenance*	
Regional history deadline by project type [c_{21}-c_{22}]	*[2-12 months plus 12 months of maintenance]*		*[2-12 months plus 12 months of maintenance]*		*[2-12 months plus 12 months of maintenance]*	
Local unemployment (c_{113}=c_{123}) Maximum and minimum national unemployment [c_{114}-c_{115}]= [c_{124}-c_{125}]	*6.01%;* *[4.1%-6.8%]*		*4.55%;* *[4.1%-6.8%]*		*5.78%;* *[4.1%-6.8%]*	
Property and habitability (i=2)						
Expropriation (r=1)	*no evidence*	*no evidence*	*no evidence*	*Right of way for 150,000 USD and 40 properties affected*	*no evidence*	*Right of way for 130,000 USD and 36 properties affected*
Max historic value paid for rights of way (c_{211})	*200,000 USD*	*200,000 USD*	*200,000 USD*	*200,000 USD*	*200,000 USD*	*200,000 USD*
Max tolerable affected properties (consensus) (c_{212})	*50*	*50*	*50*	*50*	*50*	*50*
*Current average accessibility (Without project) to : Primary education center (r=2); Secondary education center (r=3); Health center (r=4); Hospital (r=5); Commerce (r=6); Police (r=7)	*Rural health services, basic school, police are available in local area (6 km, 15' by car to the most disadvantaged population center); Secondary school, hospital, large retailers (15 km, 35' by car to the most disadvantaged population center).*		*Rural health services, basic school, police are available in local area (10 km, 45' by car to the most disadvantaged population center); Secondary school, hospital, large retailers (30 km, 135' by car to the most disadvantaged population center).*		*Rural health services, police, rural school available in local area (4 km, 13' by car to the most disadvantaged population center); Basic and secondary school, hospital, shops (15 km, 40' by car to the most disadvantaged population center).*	
Current frequency of public transport (c_{2r1})	*Public transportation 3 times per day.*		*Public transportation 6 times per day.*		*Public transportation 2 times per day*	
Safe environment (i=3)						
Safety during construction work (r=1)	*Work with machines and equipment with contiguous traffic. The roads access directly to a main way. There is strong evidence of alcoholism and crime*		*Work with machines and equipment with contiguous traffic*		*The roads access directly to a main way. There is strong evidence of alcoholism and crime*	
Safety for the operation of infrastructure (r=2)	---	*Flooding conditions will be reduced*	---	*Flooding conditions will be reduced. Improves safety on the layout of the track.*	---	---
Zonal insecurity conditions (C_{32z})	*Zone for agricultural burning, animals and heavy transport and basic school next to road*		*Presence of cliffs and extreme climate*		*Number important of people walk on the road, zone of agricultural burning*	
Citizen participation (i=4)						
Means of participation (r=1)	*no evidence*	*Communal meeting*	*no evidence*	*Communal meeting, but just receives observations of leaders*	*no evidence*	*Publication in the local newspaper*
Time of participation (r=2)	*no evidence*	*During the design*	*no evidence*	*From conceptualization by initiative of the Mayor*	*no evidence*	*Interview with random group of the community during the conceptualization*
(*)Note: Improving accessibility (travel time) is determined according to the speed of operation of the infrastructure and the distance to each center (in this case does not change).						

Table 4 provides some of the information given to the experts for evaluation of potential long-term social improvement. In particular, this information was taken into account for assessing the extent of social needs in each area (question B2.1, sub-section 4.2.2). In addition, the background of each project and the Plan of Territorial Development of El Salvador 2021 was used. This information was used to assess the potential contribution of the infrastructure in the long term (question B2.2, sub-section 4.2.2).

Table 4: Synthesis of the zone's current situation for long-term evaluation.

Social improvement goals (k) and indicators (v)	Background of context		
	Zone 1	**Zone 2**	**Zone 3**
Economy (k=1)			
Per capita income (v=1) Annual trend (10 years) Position of the region in the country [1 worst -10 best]	*450USD/month* *+1.25%;* *7*	*300USD/month* *+4%;* *4*	*285USD/month* *+0.7%;* *3*
Education (k=2)			
Average years of schooling (v=1) Annual trend (10 years) Position of the region in the country [1 worst -10 best]	*8* *+3.25%;* *8*	*6* *+2%;* *6*	*5* *+0.5%;* 2
% population with secondary education (v=2) Annual trend (10 years) Position of the region in the country [1 worst -10 best]	*75%* *+1.83%;* *6*	*55%* *+0.8%;* *5*	*35%;* *+0.2%;* 2
Health (k=3)			
Years of life expectancy (v=1) Annual trend (10 years) Position of the region in the country [1 worst -10 best]	*73* *+0.25%* *1*	*74* *+0.4%;* *8*	*68* *+0.1%* *3*
Source: Based on DIGESTYC (2014) Household Survey and purposes multiples- El Salvador (EHPM in Spanish)			

5.3. Contribution to short-term social improvement

Some variables with social implications have been highlighted in other studies with respect to transport infrastructure projects. Regarding employment, Labuschagne et al. (2005) mention its incidence during construction and maintenance of infrastructures. Meanwhile the issue of expropriation is one of the greatest concerns and interests for communities. The higher the value and the greater the number of properties affected, the greater the social upheaval (Valentin and Bogus 2015). Moreover, Gannon and Liu (1997) and Van de Walle (2009) consider accessibility as a direct impact of road infrastructure on community services. Regarding safety, the road affects the area during construction and operation (Valdes-Vasquez and Klotz 2013, Sierra et al. 2016). In this sense, the conditions of work and transit, design and the safety hazards in the area are variables that influence the social impact. The criterion of stakeholder participation is also significant in the results of infrastructure planning and execution (O'Faircheallaigh 2010).

Based on the background mentioned and interviews with specialists, a set of project variables, zone conditioning factors and interrelations were defined. These inputs enabled the structuring of the most significant transfer functions that justify the contribution to a short-term social criterion. Table 5 illustrates the specific operation carried out to estimate the transfer functions of the variables: number of contracts (i=1, k=1), construction deadline (i=2, k=2), safety during construction work (i=3, k=1) and safety for the operation (i=3, k=2). In the first and second cases, the transfer functions were modeled quantitatively according to Eq. [3]; they interact with the zonal unemployment. In the third case, four qualitative variables of project and social issues of the context were related in a transfer function. In the fourth case, two sets of ten possible situations interacted: the variables of design "p" of the project and the conditions of risk "z" of the zone.

Table 5: Transfer functions for "employment" and "safe environment" social criteria.

i	r	$f_r(X_r, C_r)$
1.- Employment	1Number of contracts	$Y_{11}^{ST} \cong \left[\frac{(X_{11}-c_{112})}{(c_{111}-c_{112})}\right]\cdot\left[\frac{c_{113}-c_{115}}{c_{114}-c_{115}}\right]$
	2 Construction deadline	$Y_{12}^{ST} \cong \left[\frac{(X_{12}-c_{122})}{(c_{121}-c_{122})}\right]\cdot\left[\frac{c_{123}-c_{125}}{c_{124}-c_{125}}\right]$
3.- Safe environmental	1 Safety during construction work	$Y_{31}^{ST} \cong \left[1-\frac{X_{31\_1}\cdot X_{31\_2}\cdot(X_{31\_3}+X_{31\_4}+\sum_{q=1}^{5}c_{31q})}{24\cdot 3\cdot 7}\right]$ For: X_{31_1} : Project deadline until 24 months X_{31_2} : Interval of annual mean daily traffic➔(3) >1000; (2) [500-1000]; (1) [100-500]; (0) <100 X_{31_3} : Does it require direct access to main roads?➔(1) Yes; (0) No X_{31_4} : Is there use of machinery and work alongside vehicular traffic? ➔(1) Yes; (0) No c_{31q} : Social issues in the context,qϵ[1 – 5]; If "q" fulfill ➔ c_{31q} = 1 , in other case c_{31q} = 0 q=1 alcoholism; q=2 crime; q=3 violence; q=4 drug; q=5 prostitution
	2 Safety in the operation of infrastructure	$Y_{32}^{ST} \cong \left[\frac{\sum_{p=1}^{10} X_{32\_p}}{m}\right]\cdot\left[1-\sum_{z=1}^{10}\frac{c_{32z}}{10}\right]$ Design variables: If "p" fulfills a standard➔ $X_{32\_p} = 100$; If "p" does not fulfill and is required ➔ $X_{32\_p} = 0$ "m" is the number of design conditions according to the characteristics of the project, with m = [1 – 10] "p" in this case are: (p=1) road equipment, (p=2) road geometry, (p=3) intersections, (p=4) pavements, (p=5) drains, (p=6) margins, (p=7) vulnerable users, (p=8) solution to pre-existing flooding conditions, (p=9) solution to disintegration or undermining, and (p=10) improvement zones along the trajectory with high accident rates. Condition of risk: If z is present ➔ c_{32z}= 1, in other case c_{32z}= 0 "z" in this case are: (z=1) flooding not improved, (z=2) landslide not improved, (z=3) social conflict zone, (z=4) agricultural burning zone, (z=5) heavy load industrial zone, (z=6) animal zone, (z=7) cliff zone, (z=8) zone under extreme climatic conditions, (z=9) school zone or contiguous meeting points on the inter-city, and (z=10) wooded zone.

Table 6 presents the facts of each project variable and conditioning factors of zone, the interaction of which establishes the social contribution of the variable. These are taken into consideration in each transfer function. For this case, the contributions present a proportionally increasing value according to the number of conditions involved on each variable.

Table 6: Aspects that determine the social contribution of the variable "r".

i	.r	Variable "r" vs. conditioning factor	Reference
1	1.- Number of monthly contracts	Number of monthly contracts vs. Intervals of contracts max and min in the zone for project type Local unemployment rate and range of national unemployment rate	Labuschagne et al. 2005 Asomani-Boateng 2015 Sierra et al. 2016
	2.- Construction deadline	Construction deadline vs. Intervals of deadlines max and min for project type vs. Local unemployment rate and range of national unemployment rate	
2	1.- Expropriation	Range of properties affected vs. Intervals of market valuation of the property to be ceded	Valentin and Bogus 2015
	2 to 7.- Accessibility to services	Ranges of travel time reduction from the most socially disadvantaged population center to the service (2) primary education, (3) secondary education, (4) health clinic, (5) hospital, (6) commerce, (7) police, v.s Frequency intervals at which public transportation passes	Asomani-Boateng 2015
3	1.- Safety	Intervals of mean annual daily traffic in the zone, vs.	Valdes-Vasquez and

	conditions of the works	Risk conditions during the work activities for the road user, surrounding community and project personnel, vs. Time limit range for work	Klotz 2013 Valentín and Bogus 2015
	2.- Safety conditions of the operation	Design conditions, v.s Improvement in conditions of the *layout of the track* with evidence of accident risk Elements of lack of safety in the independent context of the project	Porter et al. 2012
4	1.- Means of participation	Means of information that only allow closed feedback, open feedback, or are not in evidence.	Labuschagne et al. 2005 O'Faircheallaigh 2010
	2.- Initial point of participation	From project genesis and conceptualization, during the design process, beginning of construction or is not shown, vs. Level of notice: Open call, community representatives, limited and random sample	Valdes-Vasquez and Klotz 2013 O'Faircheallaigh 2010

From the background of each alternative and the zonal context, the procedure described and the use of Eqs [2], [6] and [7] followed. Table 7 shows the score results (S_i^{ST}), assessment (V_i), and STSI for each alternative. The assessment V_i is determined by assuming the incentive of the practices that promote improvement of the criteria. This in turns makes it possible to differentiate alternatives with low scores. According to the previously described recommendations by Manga (2005), the parameters used to determine V_i are A_i =0.72, m_i=0.9, n_i=100 and K_i=1.69.

Table 7: Results of social improvement from short-term infrastructure alternatives.

Alternative	i	S_i^{ST}	V_i	W_i	STSI
A1	1	44.861	0.670	0.400	0.603
	2	55.143	0.750	0.250	
	3	53.095	0.735	0.200	
	4	0.000	0.000	0.15	
A2	1	12.292	0.305	0.400	0.501
	2	80.000	0.905	0.250	
	3	57.365	0.765	0.200	
	4	0.000	0.000	0.150	
A3	1	34.441	0.577	0.400	0.590
	2	58.846	0.776	0.250	
	3	66.286	0.825	0.200	
	4	0.000	0.000	0.150	
B1	1	10.061	0.267	0.400	0.629
	2	68.952	0.841	0.250	
	3	73.460	0.868	0.200	
	4	83.333	0.922	0.150	
B2	1	5.144	0.170	0.400	0.605
	2	67.109	0.830	0.250	
	3	87.048	0.942	0.200	
	4	87.500	0.944	0.150	
B3	1	11.359	0.290	0.400	0.596
	2	51.875	0.726	0.250	
	3	86.048	0.936	0.200	
	4	54.167	0.743	0.150	

5.4. Contribution to long-term social improvement

From the review of local databases (DIGESTYC 2014), quality and representativeness for each context was checked. Then, a set of indicators was defined by experts to respond to the needs of each long-term social goal in the region. Table 4 presents the current state of the social indicators of each zone. The value of the social indicator, its trend and position of the zone within the region characterize each social indicator.

According to the procedure described, Table 8 shows the elements that determine the score "S_k^{LT}" for each social improvement goal. It displays the results of consensus on questions that identify the degree of potential benefit from the infrastructure (B.2.1) and the degree of zonal need (B.2.2). Additionally, Eq. [8] is used to determine the LTSI index from the weights of each social improvement goal (Table 1) and its score.

Table 8: Results of long-term social improvement.

Alt.	Social improvement goal k	Indicator v	B.2.1	B.2.2	Y_v^{LT}	w_v	S_k^{LT}	W_k	LTSI
A.1	Economic development k=1	Per capita income v=1	2	1	2	1	2	0.5	2.000
	Improvement in education k=2	Average years of schooling v=1	1	2	2	0.5	2	0.25	
		% population with secondary education v=2	1	2	2	0.5			
	Improvement in health k=3	Years of life expectancy v=1	1	2	2	1	2	0.25	
A.2	Economic development k=1	Per capita income v=1	3	3	9	1	9	0.5	6.375
	Improvement in education k=2	Average years of schooling v=1	2	2	4	0.5	3.5	0.25	
		% population with secondary education v=2	1	3	3	0.5			
	Improvement in health k=3	Years of life expectancy v=1	1	4	4	1	4	0.25	
A.3	Economic development k=1	Per capita income v=1	3	5	15	1	15	0.5	10.000
	Improvement in education k=2	Average years of schooling v=1	2	4	8	0.5	6	0.25	
		% population with secondary education v=2	1	4	4	0.5			
	Improvement in health k=3	Years of life expectancy v=1	1	4	4	1	4	0.25	
B.1	Economic development k=1	Per capita income v=1	4	1	4	1	4	0.5	4.750
	Improvement in education k=2	Average years of schooling v=1	2	2	4	0.5	5	0.25	
		% population with secondary education v=2	3	2	6	0.5			
	Improvement in health k=3	Years of life expectancy v=1	3	2	6	1	6	0.25	
B.2	Economic development k=1	Per capita income v=1	4	3	12	1	12	0.5	10.250
	Improvement in education k=2	Average years of schooling v=1	3	2	6	0.5	9	0.25	
		% population with secondary education v=2	4	3	12	0.5			
	Improvement in health k=3	Years of life expectancy v=1	2	4	8	1	8	0.25	
A.3	Economic development k=1	Per capita income v=1	5	5	25	1	25	0.5	18.500
	Improvement in education k=2	Average years of schooling v=1	3	4	12	0.5	12	0.25	
		% population with secondary education v=2	3	4	12	0.5			
	Improvement in health k=3	Years of life expectancy v=1	3	4	12	1	12	0.25	

5.5. Outcomes from the method

According to the described procedure illustrated in Fig. 5, six alternatives are contrasted according to the value of their LTSI and STSI indices. The graph in Fig. 8 represents the efficient solutions comprised of alternatives B1, B2 and B3. After application of compromise programming with $\lambda_1 = \lambda_\infty = 0.5$, the efficient set is prioritized in accordance with the shortest distance "d_1 and d_∞". The ordered alternatives closest to the ideal point and farthest from the anti-ideal are B3, B2 and B1.

The stability of the response is presented in Table 9 based on the performance of a sensitivity analysis of the weights. For a variation at regular intervals of the variables W_i y W_k, there are no important fluctuations in the prioritization. From a change in the short-term criterion weight of "Employment" and "Participation", over +20% and under -30% respectively, the order of solution set changes significantly.

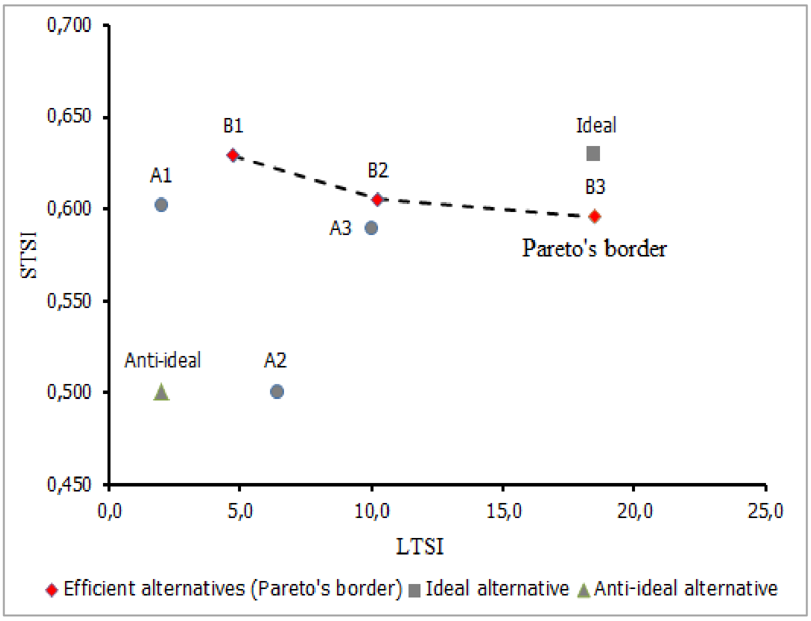


Figure 8. Socially sustainable solutions.

Table 9. Stability of variables "Weight-W_i W_k" for the solution set.

% variation	W_i				W_k		
	Employment	**Property & ability**	**Safe environment**	**Participation**	**Economy**	**Education**	**Health**
+40	**B3,A3,A1**	B3,B2,B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
+30	**B3,A3,A1**	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
+20	**B3,A3,B1,A1**	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
+10	B3, (B2-A3), B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
0	**B3, B2, B1**	**B3, B2, B1**	**B3, B2, B1**	**B3, B2, B1**	**B3, B2, B1**	**B3, B2, B1**	**B3, B2, B1**
-10	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
-20	B3, B2, B1	B3, B2, B1	B3, B2, B1	B3, (B2-A3), B1	B3, B2, B1	B3, B2, B1	B3, B2, B1
-30	B3, B2, B1	B3, B2, B1	B3, B2, B1	**B3, A3, B1, A1**	B3, B2, B1	B3, B2, B1	B3, B2, B1
-40	B3, B2, B1	B3, B2, B1	B3, B2, B1	**B3, A3, A1**	B3, B2, B1	B3, B2, B1	B3, B2, B1

6. DISCUSSION

The outcome of the method revealed that improvement projects B obtained better rates than rehabilitation projects "A". In particular, alternative B1 does not affect ownership and improve accessibility. These conditions raise its STSI index. In this respect, the high LTSI index of "B3" is the result of a potential improvement in the goal "economy". This is consistent with the need in the area and the existence of a harbor nearby that complements the project’s contribution.

In this way the case study illustrates how the method prioritizes the current and future conditions of the context. In this vein, Esteves and Vanclay (2009) consider cumulative impacts as a result of interventions. Also, Valdés-Vasquéz and Klotz (2011) and Owgu et al. (2006) regard the experience as a means to understand the relationships of future impacts. This method employs experts to estimate the social benefit of a long-term project. It also looks at the social status of the area to promote a more equitable distribution. In this respect, Gannon and Liu (1997) highlighted infrastructure as a generator of long-term development in the areas of greatest need.

The proposed method also promotes multisectoral participation in decision-making. Munda (2006) suggests that considering different viewpoints addresses the representation of all interests in a society. In addition, the inclusion of decision-makers promotes social learning. In this regard, Pellicer et al. (2016) show different profiles learning in decision-making about a sustainable infrastructure. In the long term, this implies improvements and innovations in urban and rural development for public use. An example of this can be seen in the building sector, where the assessment and certification of sustainability was developed much earlier (Ugwu et al 2006). A case in point is the “Industrialization of sustainable housing” (INVISO in Spanish) project in Spain, which contributes to social change through modular solutions and the commitment of stakeholders who make up the life cycle of the housing (Queipo et al. 2009).

According to the above, the method provides a specific and necessary treatment to the social dimension of sustainability. However, phase prioritization can integrate economic and environmental dimensions of sustainability. This idea points to a non-compensatory multidimensional approach for estimating integral sustainability solutions (Garcia-Segura and Yepes 2016). Meanwhile, the exploration of the items of projects, context and interaction on social sustainability must be strengthened. Uncertainty is also typical of a process when assessment by people is involved (Mel et al. 2015). In this regard, the way to treat the uncertainty of the input and assessment mechanism is to further improve the method.

The method has a national strategic purpose, i.e., taking into account the regions of a nation and the projects that are socially suitable. In this vein, the decision-making process acts early and is adaptable to the geographical context and type of infrastructure.

7. CONCLUSIONS

The article proposes a method to select suitable infrastructure projects from the social sustainability point of view. This method emphasizes the interactions of the infrastructure with the environment and the consideration of social improvement in the short and long term. The method is structured in five stages that seek to identify: the improvement criteria and goals; the elements of infrastructure and environment and their interaction for social improvement; the assessment according to the level of regional development; the indices of social improvement in the short and long term; and the socially efficient alternatives. The method was illustrated through six alternatives of road infrastructure improvement in three different zones.

The implementation of the method distinguishes the contribution to social sustainability of different infrastructures and location contexts. The method identifies the efficiency of a social contribution in terms of the returns of early social benefits and a distribution adapted to the long term. This proposal supports early decision-making regarding infrastructure projects and their location from the point of view of social contribution. It takes into consideration current needs, as well as future strategies for a specific zone. In this sense, it can be a tool to support public agencies in charge of infrastructure investments to promote development in different geographic scenarios.

The method can be applied prior to the implementation of a project to select the infrastructure alternatives most pertinent to a context by virtue of its social sustainability. The results can complement environmental or economic sustainability assessments. This method can be replicated in any geographic context, adapting the elements of the model to the local, regional characteristics and to the type of infrastructure.

In the future, this proposal will be broadened so that the interactions with other sustainability dimensions can be identified and measured. The intention is also to investigate the transfer relations, considering the significant elements of the infrastructures that affect social sustainability criteria.

REFERENCES

Ahmadvand, M., Karami, E., Taghi, M. (2011). "Modeling the determinants of the social impacts of agricultural development projects", *Environ. Impact Assess.*, 31(1):8-16, doi: 10.1016/j.eiar.2010.06.004

Alarcón, B., Aguado, A., Manga, R., Josa, A. (2011). "A value function for assessing sustainability: Application to industrial building", *Sustainability*, 3: 35-50, doi: 10.3390/su3010035

Alshubbak, A., Pellicer, E., Catalá, J., Teixeira, J.C. (2015). "A model for identifying owner's needs in the building life cycle", *J. Civ. Eng. Manag.*, 21(8): 1-15, doi: 10.3846/13923730.2015.1027257

Asomani-Boateng, R., Fricano, R. J., Aderkwa, F. (2015). "Assessing the socio-economic impacts of rural road improvements in Ghana: A case study of transport sector program support (II)", *Case Stud. Transp. Policy*, 3(4): 355-366, doi: 10.1016/j.cstp.2015.04.006

Colantonio, A. (2011). "Social sustainability: exploring the linkages between research, policy and practice", *European Research on Sustainable Development*, 1: 35-57, doi: 10.1007/978-3-642-19202-9_5

Cortés J.M., Pellicer E., Catalá J. (2012). "Integration of occupational risk prevention courses in engineering degree: Delphi study", *J. Prof. Issues Eng. Educ. Pract.*, 138(1), 31-36, 10.1061/(ASCE)EI.1943-5541.0000076

Dasgupta, S., Tam, E.K.L. (2005). "Indicators and framework for assessing sustainable infrastructure", *Can. J.Civil Eng.*, 32: 30–44, doi: 10.1139/l04-101

De la Cruz, M. P., Castro, A., del Caño, A., Goméz, D., Lara, M. Cartelle, J.J. (2015). "Comprehensive Methods for Dealing with Uncertainty in Assessing Sustainability Part 1: The MIVES – Monte Carlo Method", *Soft Computing Applications for Renewable Energy and Energy Efficiency*, 69-106, doi: 10.4018/978-1-4666-6631-3.ch004

DIGESTYC – Dirección General de Estadísticas y Censos (2014). Encuesta de hogares y propósitos múltiples – San Salvador, El Salvador. In http://www.digestyc.gob.sv/index.php/temas/des/ehpm/publicaciones-ehpm.html (April 2016)

Dominguez-Gomez, J.A. (2016)."Four conceptual issues to consider in integrating social and environmental factors in risk and impact assessments", *Environ. Impact Assess.*, 56 (1): 113 –119, doi: 10.1016 / j.eiar.2015.09.009

Esteves, A.M., Vanclay, F. (2009). "Social development needs analysis as a tool for SIA to guide corporate-community investment: Applications in the minerals industry", *Environ. Impact Assess.*, 29(2):137-145, doi: 10.1016 / j.eiar.2008.08.004

Fernández-Sánchez, G., Rodríguez-López, F. (2010). "A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain", *Ecol. Indic.*, 10(6): 1193-1201, doi: 10.1016/j.ecolind.2010.04.009

Foth, N., Manaugh, K., El-Geneidy, A. M. (2013). "Towards equitable transit: examining transit accessibility and social need in Toronto, Canada, 1996–2006", *J. Transp. Geogr.*, 29(1): 1-10, doi: 10.1016/j.jtrangeo.2012.12.008

Fulford, R.S., Smith, L.M., Harwell, M., Dantin, D., Russell, M., Harve, J. (2015). "Human well-being differs by community type: Toward reference points in a human well-being indicator useful for decision support", *Ecol. Indic.*, 56(1):194-204, doi: 10.1016 / j.ecolind.2015.04.003

Gannon, C. A., Liu, Z. (1997). *Poverty and Transport* (No. TWU-30), Washington, DC: World Bank.

García-Segura, T., Yepes, V., Alcala, J., Pérez-López, E. (2015) "Hybrid harmony search for sustainable design of post-tensioned concrete box-girder pedestrian bridges", *Engineering Structure*, 92: 112-122, doi:10.1016/j.engstruct.2015.03.015.

García-Segura, T., Yepes, V. (2016) "Multiobjective optimization of post-tensioned concrete box-girder road bridges considering cost, CO2 emissions, and safety", *Engineering Structure*, 125: 325-336, doi: 10.1016/j.engstruct.2016.07.012.

Gómez-López, D., del Caño, A., de la Cruz, M. (2013). "Estimación temprana del nivel de sostenibilidad de estructuras de hormigón en el marco de la instrucción española EHE-08", *Inf. Constr.*, 65(529): 65-76, doi: 10.3989/ic.11.123

Hallowell M., Gambatese, J. (2010). "Application of the Delphi method to CEM research", *J. Constr. Eng. Manage.*, 136(1):99-107, doi:10.1061/(ASCE)CO.1943-7862.0000137

Labuschagne, C., Brent, A.C., van Erck, R.P.G. (2005). "Assessing the sustainability performance of industries", *J. Clean. Prod.*, 13(4): 373–385, doi: 10.1016/j.jclepro.2003.10.007

Le Moigne, J.L.(1990). *La Modélisation des Systems Complexes*, Paris: Dunod.

Luhmann, N. (1998). *Sistemas Sociales: Lineamientos para una Teoría General*, Bogotá: Anthropos Editorial.

Manga, R. (2005). *Una Nueva Metodología para la Toma de Decisión en la Gestión de Contratación de Proyectos*. PhD Thesis, Barcelona: Universitat Politècnica de Catalunya.

Max-Neef, M. (1995). "Economic growth and quality of life: a threshold hypothesis", *Ecol. Econ.*, 15(2): 115-118, doi: 10.1016/0921-8009(95)00064-x

Mel, J., Gómez, D., de la Cruz, P. (2015). "Análisis de sensibilidad y estudio crítico del modelo de evaluación de la sostenibilidad de la Instrucción Española de Hormigón Estructural", *Inf. Const.*, 67(539), doi: 10.3989/ic.14.126

Mostafa, M., El-Gohary, N. (2014). "Stakeholder-sensitive social welfare–oriented benefit analysis for sustainable infrastructure project development", *J. Constr. Eng. Manage.*, 140(9): 04014038, doi: 10.1061/(ASCE)CO.1943-7862.0000788.

Munda, G.(2006). "Social multi-criteria evaluation for urban sustainability policies", *Land Use Policy* 23(1): 86–94, doi:10.1016/j.landusepol.2004.08.012

Noll, H.H. (2013). "Subjective Social Indicators: Benefits and limitations for policy making—An introduction to this special issue", *Soc. Indic. Res*, 114(1): 1–11, doi: 10.1007/s11205-013-0379-7

O'Faircheallaigh C. (2010). "Public participation and environmental impact assessment: Purposes, implications, and lessons for public policy making", *Environ. Impact Assess.*, 30(1): 19–27, doi: 10.1016/j.eiar.2009.05.001

Pavlovskaia, E. (2013). "Using sustainability criteria in law", *International Journal of Environmental Protection and Policy*, 1(4): 76–78, doi: 10.11648/j.ijepp.20150305.11

Pellicer, E., Sierra, L.A., Yepes, V. (2016). "Appraisal of infrastructure sustainability by graduate students using an active-learning method", *J. Clean. Prod.*, 113(1): 884-896, doi:10.1016/j.jclepro.2015.11.010

Porter, R., Donnell, E., Mason, J. (2012). "Geometric design, speed, and safety", *Transportation Research Record: Journal of the Transportation Research Board*, 2309, 39-47, doi: 10.3141/2309-05

Queipo, J., Navarro, J.M., Izquierdo, M., Aguila, A., Guinea, D., Villamor, M., Vega.S., Neila, J. (2009). "Proyecto de Investigación INVISO: Industrialización de Viviendas Sostenibles", *Informes de La Construcción* 61(513): 73–86, doi:10.3989/ic.09.001.

Saaty, T.L., (1987). "The analytic hierarchy process – What it is and how it is used", *Math. Model*, 9(3–5), 161–176. doi:10.1016/0270-0255(87)90473-8

Sierra, L., Pellicer, E., Yepes, V. (2016). "Social sustainability in the life cycle of Chilean public infrastructure", *J. Constr. Eng. Manage.*, 142(5), 05015020, doi: 10.1061/(ASCE)CO.1943-7862.0001099

Torres-Machi, C., Chamorro, A., Pellicer, E., Yepes, V., Videla, C. (2015). "Sustainable pavement management: Integrating economic, technical and environmental aspects in decision making", *Transportation Research Record: Journal of the Transportation Research Board*, 2523:56-63, doi: 10.3141/2523-07

Torres-Machí, C., Chamorro, A., Yepes, V., Pellicer, E. (2014). "Current models and practices of economic and environmental evaluation for sustainable network-level pavement management", *Revista de la Construcción*, 13(2): 49-56, doi: 10.4067/S0718-915X2014000200006

Ugwu, O.O., M.M. Kumaraswamy, A. Wong, S.T. Ng. (2006a). "Sustainability Appraisal in Infrastructure Projects (SUSAIP) Part 1: Development of indicators and computational methods", *Automation in Construction* 15 (2): 239–251. doi:10.1016/j.autcon.2005.05.006.

Ugwu, O.O., M.M. Kumaraswamy, A. Wong, S.T. Ng. (2006b). "Sustainability Appraisal in Infrastructure Projects (SUSAIP) Part 2: A case study in bridge design", *Automation in Construction* 15 (2): 229–238. doi:10.1016/j.autcon.2005.05.005.

UN (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*, New York: United Nations Organization (UN).

Valdés-Vásquez, R., Klotz L.E. (2013). "Social sustainability considerations during planning and design: framework of processes for construction projects", *J. Constr. Eng. Manage.*, 139(1): 80-89, doi: 10.1061/(ASCE)CO.1943-7862.0000566

Valentin, V., Bogus, S. (2015). "Assessing the link between public opinion and social sustainability in building and infrastructures projects", *J. Green Build.*, 10(3): 177-190. doi: 10.3992/jgb.10.3.177

Van de Walle, D. (2009). "Impact evaluation of rural road projects", *Journal of Development Effectiveness*, 1: 15-36, doi: 10.1080/19439340902727701

Xing, K., Ness, D., Lin, F. (2013). "A service innovation model for synergistic community transformation: integrated application of systems theory and product-service systems", *J. Clean. Prod.*, 43(1): 93-102, doi: 10.1016/j.jclepro.2012.11.052

Yepes, V., Martí, J.V., García-Segura, T. (2015a). “Cost and CO2 emission optimization of precast-prestressed concrete U-beam road bridges by a hybrid glowworm swarm algorithm”, *Automat. Constr.*, 49: 123-134, doi: 10.1016/j.autcon.2014.10.013

Yepes, V., Garcia-Segura, T., Moreno-Jimenez, J.M. (2015b). “A cognitive approach for the multi-objective optimization of RC structural problems”, *Arch. Civil Mech. Eng.*, 15(4): 1024-1036, doi:10.1016/j.acme.2015.05.001