Evaluation of the Social Sustainability of Infrastructure Projects: A Case Study of Urban Road Improvement in Southern Chile

D González¹, B Henríquez¹, L Sierra¹

¹Departamento de Obras Civiles, Universidad de la Frontera, Av. Fco. Salazar, Temuco 01145, Chile.

E-mail:b.henriquez01@ufromail.cl, d.gonzalez25@ufromail.cl, leonardo.sierra@ufrontera.cl.

Abstract. The concept of sustainability in civil works projects has been addressed mainly from economic and environmental perspectives. However, by definition, a holistic view must incorporate the social component. It is fundamental to understand the social interactions related to the life cycle of a civil work; otherwise harmonic coexistence is not promoted and risks a conflict between the community and the institutions responsible. Here, a case study is presented that analyses the contribution of an urban road improvement project to social sustainability in an area of a city with high traffic and renovation. The study is divided into two parts: first, the conceptual structure that relates the social criteria and the stakeholders involved in each stage of the life cycle of the project is established. Then, the indicators and thresholds are determined according to the implementation context. The methodology is based on semi-structured interviews with the stakeholders, a document review and surveys with the community. From this work, socially critical stakeholders and the dominant stages of the life cycle are identified. The construction of bicycle lanes and road safety stand out as important criteria that contribute to long-term social sustainability, while others such as citizen participation and identity and culture are opportunities for improvement in the early stages of development.

1. Introduction
The concept of sustainability is relatively new; however, it has dominated the topics of interest in the field of infrastructure [1]. In its origin [1], it predicts a failure in the world economy for not changing the way in which infrastructure interacts with the environment. The Brundtland Report [2] defined for the first time the concept of sustainable development. However, since then the policies have been concerned mainly with assessing the environmental and economic impact of projects, leaving the social aside [3].

A sustainable project must by definition be holistic in scope [4]. From the social perspective, a project must not only consider the impact on the end user, but also on the community and stakeholders involved [5]. Indeed, social sustainability depends on the related social interactions at every stage of the life cycle of the project [5]. Understanding the social interactions improves decision-making so as to obtain the best social contribution of a project [6].
According to [6], community stakeholders must be involved in the analysis from the planning stage to identify the impacts and determine their level of interest. For his part, [8] suggests that these can be divided into groups of stakeholders interested in different aspects of the project.

For a social analysis, certain procedures and criteria must be defined, which in practice can be highly variable [7]. In this study, first the social criteria, stakeholders and the relation between them were defined during each stage of the life cycle of the project “Improvement Av. Pedro de Valdivia between Av. Orbital and Prieto Norte” in Temuco, Chile. Then, the social indicators used to quantify each of the criteria and the measurement values were specified.

This study was motivated by the paucity of literature that contributes documented implementation strategies to assess social aspects in their interaction with stakeholders and infrastructure life cycle. This lack of analysis carries with it a high risk of conflict between the community and the institutions responsible. This can cause economic losses and social damage before, during and after the construction of the project.

The case study is described in the following paragraphs of this article. Then, the methods to identify the social criteria, the project stakeholders and their interrelation in the stages of the project are presented. In addition, the procedure to implement the measurement of the social contribution of the case study is provided. Next, the results set out the interaction between the social criteria and the stakeholders. Finally, work strategies are proposed to mitigate the conditions that reduce the social contribution and strengthen those that are highly favorable as noted in the conclusions of this document.

2. Project Description
Temuco is the capital of the Region of La Araucanía, with 410,520 inhabitants in an urban area of 864.7 km2. Pedro de Valdivia Avenue is one of the structural roads of the town center that gives access to the southwestern area of the city and neighboring townships. Pedro de Valdivia Avenue is a critical point due to its increasing lack of safety for vehicular and pedestrian traffic. This project seeks to improve the connectivity between the northwestern and central sectors of Temuco.

The case study corresponds to the project “Improvement of Pedro de Valdivia Ave. between El Orbital Ave. and Prieto Norte”. This project was ordered by the Housing and Urban Planning Service (SERVIU) and construction began on May 2, 2018 for a term of 24 months.

The project consists of improving 4.4 km of the existing two-way street (Figure 1). The improvement entails widening to two lanes in each direction, construction of a central median, improvement of the pedestrian spaces and construction of bicycle lanes. In addition, construction of a roundabout and road bridges to improve the connectivity with at least three main heavily trafficked trunk roads is also included. The proposed improvement carries an investment of 43 billion Chilean pesos (USD 64 million).
3. Methodology

Figure 2 represents the methodological structure implemented in this study, which was divided into four stages, and the input and output elements.

3.1. Input
At the outset, the scope of the project is defined and the data authorizations and access to field visits are obtained. Thus, it was possible to discover the stakeholders and the framing of the exploratory analysis early on. These are the input elements for stage 1.

3.2. Stage 1
Stage 1 structures the exploratory analysis on the basis of the application of three tools: semi-structured interviews, field visits and a document review. The aim of the interviews is to explore the interest and determinants of each stakeholder with respect to the project. The documents used for the document review are tender dossiers, technical specifications, regional newspapers and feasibility studies.

3.3. Stage 2
In Stage 2, each interview is reviewed through a content analysis [8]. Thus, the stakeholders and social impacts of the project are inferred. The impacts are categorized in social criteria. If other non-defined stakeholders are found in the early detection, Stage 1 is re-done to study the new stakeholder.

Once the overall analysis of the project has been done, triangulation matrices [9] of the social criteria and stakeholders in the different stages of the life cycle are configured. This process is carried out with the support of three researchers.
The interrelation between criteria, life cycle stages and stakeholders is synthesized in a new matrix resulting from stage 2. This interrelation corresponds to the input data needed for stage 3.

3.4. Stage 3
Stage 3 corresponds to the formulation of the social indicators. The Danish National Strategy for Sustainable Development defines an indicator as a constructed parameter that illustrates developments of a condition or a context in relation to realising important objectives or initiatives [10]. Indicators can describe a temporary situation or trend and can contribute particular information on a criterion that is being measured [11].

Levett [12] notes that the process of finding indicators involves testing, criticizing and discarding to refine the possible indicators until arriving at a clear meaning of sustainability with regard to a certain system. For this study, 31 social indicators are defined. These were added by arithmetic average to obtain a single value per criterion.

3.5. Stage 4
In Stage 4 measuring and formulation tools are applied based on surveys, interviews, document reviews, definition of scales and measurement standardization. The surveys are structured as multiple choice. In addition, in order to project the assessment of indicators in the operational phase, information from homogenous projects in terms of similar traffic and context characteristics is standardized. Some documents where additional information was obtained are price lists from the property register, real estate brokers’ databases in the commune and the 2017 Census [13].

The measurement of each indicator is standardized on a representative scale for the entire project. In order to standardize the measurement, a 5-point Likert scale is used, where 5 and 1 represent the values of greatest and least contribution to social sustainability respectively. In order to determine the maximum and minimum values of each indicator, interviews with experts in adjustment to the context
(criteria 1.1 to 4.1 and criteria 6.1 to 13.2) and urban planning studies and databases (criteria 3.2 to 5.2) were used. According to [14] and [15], linear functions are adopted to standardize the indicators.

In order to process the evaluation, the value of the indicators is fitted to the conditions indicated in Equation 1. In Equation 1, $x_o$ is defined as the original value of the indicator, $x$ the input value for the normalization functions and $x_d$ and $x_f$ the extreme values (i.e., those defined as the most unfavorable and favorable respectively for each indicator). The normalization functions only show the variation of the indicator within a defined range (between $x_d$ and $x_f$). For values of $x_o$ outside this interval, the functions acquire values 1 or 5. Thus, in the case where $x_o$ is greater than the maximum between $x_d$ and $x_f$, or less than the minimum, $x$ will take the value corresponding to the maximum or minimum between $x_d$ and $x_f$, as required.

$$x = \begin{cases} 
  x_d, & x_o \in [\min(x_d,x_f), \max(x_d,x_f)] \\
  \min(x_d,x_f), & x_o \leq \min(x_d,x_f) \\
  \max(x_d,x_f), & x_o \geq \max(x_d,x_f) 
\end{cases} \quad (1)$$

The formulation of each indicator is obtained from a linear interpolation between the points $(x_d,1)$ and $(x_f,5)$. Note that $x_d$ can be both less or greater than $x_f$, which is why negative and positive slopes are obtained.

The minimum value of each indicator implies that the project does not contribute to social sustainability. This assessment takes into account the degree of contribution to social sustainability.

4. Output
The results of the indicators and their impact on the construction and operation are compared. In addition, a spider chart represents the score of each criterion. Additionally, qualitative results are obtained that provide information on the judgments, attitudes or desires of the stakeholders [16]. These results correspond to the output elements.

5. Results
According to the procedure described in Stage 2, the social criteria relevant to the case study were identified. Each criterion is represented by one or a set of impacts. Table 1 presents the criteria defined for the study with their respective definitions and the impacts from which each criterion is defined.

| Criterion                    | Description                           | Impacts                                      |
|------------------------------|---------------------------------------|----------------------------------------------|
| Work                         | Change in family support              | Income reduction for commercial tenants      |
|                              |                                       | Expropriation of commercial premises        |
| Comfort                      | Neighbors inconvenienced by the       | Suspended particles                          |
|                              | construction                         | Noise pollution and vibration                |
| Aesthetics and Degradation   | Harmony with the environment          | Presence of aesthetic elements               |
| Recreation and leisure       | Quantity and quality of green spaces  | Creation of green spaces                     |
|                              | Inclusion of new non-motorized        | Existence of bicycle lanes                   |
|                              | modes of transportation               | Integration of signage                       |
|                              |                                       | Dimensions of the sidewalks                  |
|                              |                                       | Inclusion of signage                         |
| Road safety                  | Elements of user protection           | Number of speed bumps                        |
|                              |                                       | Existence of traffic lights                  |
| Construction safety          | Prevention of construction-related    | Work accidents                               |
|                              | risks                                 | Prevention measures                          |
### Table 2. Indicators according to each social criterion and life cycle stage.

| Criterion                  | Life Cycle | Indicator                                                                 | Origin of the information                      |
|---------------------------|------------|---------------------------------------------------------------------------|-------------------------------------------------|
| Health                    |            | Health risks due to construction and demolition works                      | Unhealthy conditions due to illegal occupation of expropriated houses. |
| Alteration to services    |            | Changes in the offering of basic services                                 | Disruption of basic services                     |
| Traffic                   |            | Congestion produced by detours                                            | Increase in vehicular congestion                 |
| Added value               |            | Real or speculated changes in the value of a property                      | Alteration in the property value                 |
| Participation             |            | Community intervention in the project                                     | Neighborhood meetings                             |
| Identity and Culture      |            | Neighbors’ identification with the neighborhood                           | Participation in neighborhood groups           |

Table 2 presents the criteria used and the life cycle stage in which they were included. In addition, the origin of the information that assesses each indicator is shown.
The interviews, the field work and the analysis described in Stage 2 of the methodology yields the matrix that synthesizes the interaction between stakeholders, criteria and life cycle stages. This matrix is represented in Figure 3, where each side corresponds to the criteria, stakeholders and life cycle stages that were used. It is important to note that this interaction represents a static condition for the point at which the case study is analyzed.

The results of each indicator are shown in Table 3. In addition, the favorable and unfavorable parameters (maximums and minimums) and the standardization equation are indicated.

![Figure 3. Interaction matrix of social criteria, stakeholders and life cycle stages.](image-url)
The column marked “Unit” determines the quantification measurement of the indicators that measure the criteria selected for the case study. The value is obtained from the sources identified in Table 2. These values correspond to the value without standardizing. Each equation is obtained by applying linear functions as described in the previous section.

Table 3: Non-standardized social indicator values.

| Indicator                                                                 | Unit       | Value | Most unfavorable value (x_d) | Most favorable value (x_f) | Equation            |
|---------------------------------------------------------------------------|------------|-------|------------------------------|---------------------------|---------------------|
| Difference in income resulting from the works                             | %          | 37    | >100                         | 0                         | y = −4x + 5         |
| Difference in income resulting from the project                           | Restaurant | %     | <0                           | >100                      | y = 4x + 1          |
|                                                                             | Clothing store | %     | <0                           | >100                      |                     |
| Job creation                                                              | N°/100m    | 7.43  | 0                            | 15                        | y = 0.26x + 1       |
| 2.1. Number of complaints per month                                       | N°/month   | 4     | 4                            | 0                         | y = −x + 5          |
| 2.2. Level of inconvenience due to the work                               | 1 to 5     | 2.64  | 5                            | 1                         | y = x               |
| 3.1. Acceptance of the aesthetics                                         | 1 to 5     | 4.56  | 1                            | 5                         | y = x               |
| 3.2. Green surface                                                        | %          | 21.3  | 0                            | 100                       | y = 4x + 1          |
| Difference in recreation infrastructure that the project generates         | km         | 6     | 0                            | 4.4                       | y = 0.9x + 1        |
|                                                                             | m2/inhab   | 0.51  | 0                            | 9                         | y = 0.4x + 1        |
|                                                                             | N°/bench   | 0.45  | 0                            | 1                         | y = 4x + 1          |
|                                                                             | N° blocks  | 1.82  | 0                            | 1                         | y = 4x + 1          |
|                                                                             | N° c/50 m  | 4.3   | 0                            | 4                         | y = x + 1           |
| 5.1. Length of bicycle lane                                               | km bike/ km project | 1.27  | 0                            | 1                         | y = 4x + 1          |
| 5.2. Increase width of sidewalk                                           | %          | 117   | <0                           | >100                      | y = 4x + 1          |
| 6.1. Number of safety elements                                            | N°/year    | 0     | 5                            | 0                         | y = −0.8x + 5       |
| 6.1.1. Traffic lights                                                     | N° intersections with traffic lights | 6     | 0                            | 6                         | y = 0.67x + 1       |
| 6.1.2. Pedestrian crossing                                               | N°/150m    | 1     | 0                            | 1                         | y = 4x + 1          |
| 6.1.3. Street lights                                                      | N°/150m    | 15    | 0                            | 15                        | y = 0.15x + 1       |
| 6.2. Minor accidents                                                      | N°/year    | 0     | 5                            | 0                         | y = −0.8x + 5       |
| 6.3. Moderate accidents                                                   | N°/year    | 1.5   | 4                            | 0                         | y = −x + 5          |
| 6.4. Serious accidents                                                    | N°/year    | 0     | 1                            | 0                         | y = −4x + 5         |
| 7.1. Construction risks and impact                                        | N°/year    | 0     | 100                          | 0                         | y = −0.04x + 5      |
| 8.1. Health risks and impact                                              | 0 to 100   | 24    | 100                          | 0                         | y = −0.04x + 5      |
| 9.1. Duration and importance of alteration of services                    | 1 to 5     | 1     | 5                            | 1                         | y = x               |
| 10.1. Reduction in road width due to works                                | %          | 50    | 100                          | 0                         | y = −0.04x + 5      |
| 10.2. Increased road width                                                | %          | 23    | 0                            | >100                      | y = 4x + 1          |
Each indicator was standardized on a scale from 1 to 5 according to what was described in Stage 4 of the methodology section. Thus, the indicators are grouped by criterion with the arithmetic mean of their standardized value. Figures 6 and 7 show the contribution of each criterion to social sustainability for the construction and operation stages respectively.

**Table 1.**

| Indicator                                                      | %   | 0   | 50 | $y = 8x + 1$ |
|---------------------------------------------------------------|-----|-----|----|--------------|
| 11.1. Difference in property values as a result of the project| %   | 15  | 0  | 50           |
| 12.1. Number of meetings recorded                             | N°  | 3   | 0  | 6            |
| 12.2. Elements included in the project                        | %   | 40  | 0  | 100          |
| 13.1. Level of identification with the project                | %   | 54  | 0  | 100          |
| 13.2. Commitment and participation in community               | %   | 20  | 0  | 100          |

Figure 4. Social contribution to the short-term criteria.
From Figures 4 and 5 the area of the polygon is calculated according to the score of each criterion and the contribution percentage with respect to the possible maximum area with five points. From this, it is obtained that the contribution to the social sustainability of the project is 60% for the short-term criteria and 47% for the long-term criteria. The most common short-term criteria are construction safety, alteration to services and road safety during construction. Conversely, the most common long-term criteria are ecological mobility and road safety. These criteria determine the overall contribution of the project “Improvement of Pedro de Valdivia Avenue” to the social development of the context in which it is undertaken.

Figure 6 presents each stakeholder’s contribution to social sustainability in each stage of the project. In addition, the mean and standard deviation of the social contribution of each stage is provided. Some stakeholders do not have a value, as they cannot show an interest in some of the criteria or in the participation in certain life cycle stages.
Figure 6. Contribution to social sustainability according to stakeholder in (a) design, (b) construction, (c) operation and (d) maintenance stages

SERVIU and Municipality of Temuco stakeholders receive the greatest contribution in the design and operation stages. For their part, the road users are relevant in the construction and maintenance processes. It is worth noting that the high contribution by the SERVIU and Municipality of Temuco stakeholders is due to the adequate representation of the community’s interests by these entities. The direct interests of the community in and of themselves are diverse and the effects are redistributed; this implies that the contribution received is impaired.

The semi-structured surveys revealed the community’s appraisal of the situation without the project, the contributions of the project and concerns about the construction process.

For the situation without the project, the general assessment is summarized into two large concepts: unsafe neighborhood and poor aesthetic and neighborhood image. The former is due to the high rate of crime and traffic accidents, whereas the latter is supported by the neighbors’ assertion regarding the social stigma of living in the neighborhood.

The contributions of the project that the neighbors visualize include the improvement to the neighborhood image, improvement in safety, commercial growth and the contribution to development.

On the other hand, the neighbors indicate concern for citizen participation and the project deadlines. For the first concern, there is a lack of credibility in the process in general and its results, i.e., with respect to the effective consideration within the project of the topics discussed in the meetings. Similarly, there is uncertainty in the fulfillment of project deadlines.
6. Conclusions

A social assessment is made of an urban road improvement project where the significant social variables, stakeholders and life cycle stages interact.

The contribution of the project to each stakeholder and social criterion was identified from the assessment process.

The importance of the study lies in: (1) a list of replicable criteria and indicators being proposed to evaluate such projects, (2) a threshold being established to assess the social interaction between the project and its surroundings, and (3) this analysis methodology allowing for comparative decision-making between projects. The assessment method contributes a tool to diagnose the impact and the contribution of urban public infrastructure projects to social sustainability.

In terms of the limitations of this study, it may be that the results are valid for the geographic areas and the period of evaluation experienced. Future lines of enquiry can point to the development of the standardization of a method and scales that determine a social assessment for each context and infrastructure. In addition, the methodological treatment of the stakeholders to lead to results in less development time may be of relevance.

From this study it is recommended that strategies be created that incorporate effective policies of citizen participation throughout the entire life cycle of the project. In addition to this, it is recommended that mechanisms be incorporated that ensure the effective delivery of the results of the participation process to all the stakeholders involved.

Acknowledgements

The authors wish to thank the Technical Inspection team, SERVIU Araucanía, for their collaboration with the project. In addition, this study was supported with funding from Universidad de La Frontera project DI 18-601 and the National Council for Science and Technology (CONICYT) for FONDECYT Initiation project 11190501.

References

[1] P. Bocchini, M. Asce, D.M. Frangopol, D.M. Asce, T. Ummenhofer, T. Zinke, Resilience and Sustainability of Civil Infrastructure: Toward a Unified Approach, J. Infrastruct. Syst. 20 (2014) 1–16. doi:10.1061/(ASCE)IS.1943-555X.0000177.
[2] World Commission on Environment and Development, Report of the World Commission on Environment and Development: Our Common Future Towards Sustainable Development 2. Part II. Common Challenges Population and Human Resources 4, Oslo, 1987. http://www.un-documents.net/our-common-future.pdf (accessed October 12, 2018).
[3] E. Eizenberg, Y. Jabareen, Social Sustainability: A New Conceptual Framework, Sustainability. 9 (2017). doi:10.3390/su9010068.
[4] C. Cuello, Toward a holistic approach to the ideal of sustainability, Techné. 2 (1997) 41–48. doi:10.5840/techne19972227.
[5] R. Valdes-Vasquez, L.E. Klotz, Social Sustainability Considerations during Planning and Design: Framework of Processes for Construction Projects, J. Constr. Eng. Manag. 139 (2013) 80–89. doi:10.1061/(ASCE)CO.1943-7862.0000566.
[6] L.A. Sierra, V. Yepes, E. Pellicer, Assessing the social sustainability contribution of an infrastructure project under conditions of uncertainty, Environ. Impact Assess. Rev. 67 (2017) 61–72. doi:https://doi.org/10.1016/j.eiar.2017.08.003.
[7] R. Kvam, Evaluación del Impacto Social serie del BID sobre riesgos y oportunidades ambientales y sociales, 2018. https://publications.iadb.org/bitstream/handle/11319/8917/Evaluacion-del-impacto-social-web.pdf?sequence=3&isAllowed=y (accessed October 12, 2018).
[8] M. Vaismoradi, H. Turunen, T. Bondas, Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study., Nurs. Health Sci. 15 (2013) 398–405. doi:10.1111/nhs.12048.
[9] F. Cisterna Cabrera, Categorización y triangulación como procesos de validación del
conocimiento en investigación cualitativa., Theoria. 14 (2005) 61–71. http://www.redalyc.org/articulo.oa?id=29900107.

[10] [Gobierno Danés, Et bæredygtigt Danmark – Udvikling i balance, Copenhagen, 2014.

[11] [H. Gudmundsson, Making concepts matter: sustainable mobility and indicator systems in transport policy n, (2003).

[12] R. Levett, Sustainability indicators - Integrating quality of life and environmental protection, J. R. Stat. Soc. Ser. A Stat. Soc. 161 (1998) 291–302. doi:10.1111/1467-985X.00109.

[13] INE, Resultados Censo 2017, (2017). http://www.censo2017.cl/descargue-aqui-resultados-de-comunas/ (accessed July 12, 2018).

[14] CESBA, Assessment for Buildings and Neighbourhoods, in: Cesba – a Collect. Initiat. a New Cult. Built Environ. Eur., Cesba Guid., CESBA, CESBA, 2014: p. 22.

[15] COIN, 10 Step Guide, Competence Cent. Compos. Indic. Scoreboards. (2019). https://composite-indicators.jrc.ec.europa.eu/?q=10-step-guide/step-5-normalisation (accessed August 10, 2019).

[16] E. Contreras, J.F. Pacheco, Evaluación Multicriterio para Programas y Proyectos Públicos, Santiago, 2007.