PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
ESCUELA DE INGENIERIA

ADAPTABLE MODEL TO ASSESS SUSTAINABILITY IN HIGHER EDUCATION: APLICATION TO FIVE CHILEAN INSTITUTIONS

FRANCISCO J. URQUIZA

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering

Advisor:
CÉSAR A. SÁEZ NAVARRETE

Santiago de Chile, January, 2013

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To my parents and to my beloved Monse

ACKNOWLEDGEMENTS

César Sáez was the first person who believed in my research proposal. César devoted much time to advising this research keeping me on track. For this I am extremely grateful.

Jaime Cornejo was very helpful in the final phase of my research, stimulating me to consider new approaches and conclusions that will influence future research deriving from this one. Shirley Booth provided important help with regard to the design of the survey, which was a key element of my research. Héctor Jorquera provided advice on the most adequate form of presenting the methods and results of the research. To all them I am very grateful.

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RESUMEN

El presente estudio tiene dos objetivos principales. En primer lugar, el desarrollo de un modelo para evaluar el grado de implementación de la sustentabilidad en Instituciones de Educación Superior (HEI) que sea aplicable a distintos contextos, independiente de sus avances y de la información disponible. En segundo lugar, la aplicación de dicho modelo en el contexto Chileno para indagar sobre el desempeño nacional en esta materia.

El modelo utilizado para la evaluación se basa cuatro niveles jerarquizados, considerando tres criterios principales: compromiso institucional (IC), ejemplo interno (SE) y promoción externa de la sustentabilidad (EP). El modelo fue probado en cinco instituciones de educación superior chilenas que contaban con reportes de sustentabilidad o equivalentes, en el año 2010. Los pesos de los criterios e indicadores se determinaron a través de consultas a expertos, utilizando el Proceso de Análisis Jerárquico (AHP) (Saaty, 1987). Los resultados de dicho proceso mostraron una preferencia por los criterios IC y SE con pesos de 36,1% y 38,2%, respectivamente; y menos preferencia por el criterio de EP con un peso 25,7%.

En la aplicación al contexto chileno la Pontificia Universidad Católica de Chile fue la mejor evaluada con un puntaje de 0,552, seguida de la Universidad del Bío-Bío con 0,424 y la Pontificia Universidad Católica de Valparaíso con 0,350. La mayoría de las instituciones mostraron un comportamiento dispar entre los criterios de evaluación y todas tuvieron un bajo desempeño en lo que respecta al compromiso institucional, con un puntaje promedio de 0,23. Próximos estudios considerarán la evaluación de más IES chilenas, incorporando información comparativa entre distintos periodos de tiempo para evaluar la evolución del proceso.

ABSTRACT

The present study has two main objectives. In first place, the development of a model, the Adaptable model for Assessing Sustainability (AMAS), to assess the degree of implementation of sustainability in Higher Education Institutions (HEI) that would enable the assessment of sustainability under different institutional context and data availability scenarios. In second place, the application of this model to various Chilean HEI in order to establish the national performance in this area.

The AMAS model is based on a hierarchy of four levels and considers three main criterions: institutional commitment (IC), setting an example (SE), and encouragement for sustainability (ES). The model was tested in five Chilean HEI that had produced sustainability reports or equivalent for the 2010 period. The relative weights of criteria and indicators were determined through consultation with experts using the analytic hierarchy process (AHP) (Saaty, 1987). The results of this process showed a preference for the IC and SE criteria with 36.1% and 38.2%, respectively, and less preference for the ES criterion with a 25.7% weight.

Regarding the application of AMAS to Chilean HEI, the Catholic University of Chile was the best rated with a score of 0.552, followed by the University of Bío-Bío with 0.424 and the Catholic University of Valparaiso with 0.350. Most institutions showed an uneven behavior with respect to the evaluation criteria and all performed poorly in regards to the institutional commitment criterion, with an average score of 0.23. Future studies should consider the evaluation of more Chilean HEI incorporating comparative information for different time periods in order to determine the evolution of the process.

Keywords: Adaptable Model for Assessing Sustainability (AMAS), Sustainability assessment, sustainability in higher education institutions.

1. INTRODUCTION

Sustainable development (SD), defined as "development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations" (WCED, 1987), represent a major challenge in the XXI century, and education has been recognized as the best hope and most effective means in the quest to achieve it (UNESCO, 1997).

The United Nations declared the period 2005-2014 the Decade of Education for SD which established an international mandate to incorporate the principles, values and practices of sustainability in all aspects of the educational process (UNESCO, 2005). At the university level, the mandate is to reach campus sustainability

Although sustainability and sustainable development are usually used as synonymous, they are quite different. SD is focused on the process, and as Ehrenfeld claims can be understand as "an extrapolation of the past, except that we intend to be more efficient and fair in going about our business" (Ehrenfeld, 2004). Plus development is usually associated with growth, and "therefore SD means ameliorating, but not challenging, continued economic growth."(Robinson, 2004). Sustainability on the other hand "focuses attention where it should be placed, on the ability of humans to continue to live within environmental constraints" (Robinson, 2004). Ehrenfeld proposed to understand "sustainability as the possibility that human and other forms of life will flourish on Earth forever". The present study takes this definition as a reference associated to the idea campus sustainability.

Higher Education Institutions (HEI) have a "moral responsibility to increase the awareness, knowledge, skills, and values needed to create a just and sustainable future" (Cortese, 2003), especially because they prepare "most of the professionals who develop, lead, manage, teach, work in, and influence society's institutions…" (Cortese, 2003).

It is important to consider that students learn from everything around them, including curricula, research, operations and outreach activities establishing a complex network of experiences that define the profile of graduates (Cortese, 2003; Orr, 1991). It follows then that the process of implementing sustainability needs to cover all functions and activities of the HEI.

In order to confront this challenge the HEI "require methods of comparison to each other as well as to a vision of a sustainable college or university to ensure that they are moving in the right direction" (Shriberg, 2002). That vision has been in part recognized in a series of international declarations (e.g. Talloires, Abuja, Barcelona) which "provide guidelines or frameworks for HEI to better embed sustainability into their system" (Lozano, Lukman, Lozano, Huisingh, & Lambrechts, 2011). This vision needs to be complemented with comprehensive assessment tools that facilitate this process "through identification of best practices and focusing campus efforts on continual improvement" (Shriberg, 2002).

Many tools have been developed in order to assess the advancement towards sustainability in HEI. Shriberg has analyzed eleven of those tools, which provided "valuable insight into essential attributes of sustainability in higher education" (Shriberg, 2002), "but do not permit comparison between campuses" (Lukman, Krajnc, & Glavič, 2010).

More recently, new tools have been developed. Establishing interesting proposals that integrate the sustainability assessment for HEI with other assessment and reporting methodologies. However, even though these tools have been applied to an increasing number of institutions, their impact remains low, focusing mainly in HEI from North America and Europe.

This study presents a discussion related to four new approaches, followed by a proposal for an Adaptive Model of Sustainability Assessment (AMAS) based on a flexible framework, which allows continuous improvement and local calibration in

order to facilitate the assessment process in a broader context, including countries where the effort to implement sustainability in HEI is at early stage of development. Finally the proposed model is fully applied to five HEI in Chile.

The research document is presented in two main parts. First a comprehensive introduction covering objectives, literature review, methods, results and conclusions, followed by a research paper which covers the proposal for the adaptable model.

1.1. Research questions and objectives

The objectives of this study where constructed in order to answer the following research questions:

a) Is it possible to devise a model to evaluate and compare the implementation of campus sustainability for a broad range of higher education institutions?
b) What is the status of the implementation of campus sustainability in Chilean HEI?

Overall objective

To develop and test an assessment model for sustainability in HEI, within different implementations stages and data availability scenarios.

Specific objectives

a) To develop an assessment model based on a limited set of variables that meet the following criteria:
    i. Variables are representative of the sustainability efforts in the HEI context.
    ii. Variables are based on available information either in web media or public reports such as sustainability and accreditation reports.
    iii. Variables contain meaningful information for HEI stakeholders.

b) Apply the model to Chilean context.
c) Discuss the status of implementation of sustainability in HEI of Chile.

1.2. Hypothesis

The state of implementation of sustainability in Chilean HEI is emerging, maintaining either an environmental management focus or a curricular and research focus, failing to integrate operational and academic functions.

1.3. Literature review

The study considered a review of declarations and publications on the subject of sustainability in higher education divided in two stages. The focus was initially placed on international declarations oriented towards building a framework for the higher educational system, and used to detect and organize the main topics covered in the process of implementing campus sustainability. After that, a review of four assessment models, chosen because of their originality and popularity within the international context, was oriented towards considering their strengths and weaknesses in regard to the process of designing the new model.

1.3.1. A framework for higher education institutions (HEI)

International declarations of sustainability, give a vision of what kind of transformations are required to fulfill the goal of embedding sustainability in the system of higher education. For instance, the following elements have been highlighted in previous revisions (Lozano et al., 2011):

- Inclusion of sustainability throughout the curricula in all disciplines;
- 'Educating-the-educators' on how to educate their students in SD and help foster multiplier effects;
- Encouragement of sustainability research;
- Move towards more sustainability orientated university operations;

- Implementing sustainability through campus experiences, by incorporating it into the day-to-day activities in the university life experience;
- Stakeholder, e.g. public, governments, non-governmental organizations (NGOs) and businesses, collaboration, engagement and outreach;
- Fostering university collaboration;
- Transdisciplinarity;
- Assessment and reporting;
- Including sustainability in the institutional framework.

To comprehend how these themes and elements can be integrated in HEI is important to understand how this type of system works, and how it can be understood from a sustainability point of view. Cortese (2003) proposed a model of four interdependent dimensions: Education, Research, Operations and Community Outreach (Cortese, 2003), to which Lozano added a fifth dimension named Assessment and Reporting (Lozano, 2006a). However, these dimensions only cover what HEI do, without considering who is behind those practices and how they are related and performed (Rencoret, 2011). In order to clarify how the elements stated above can be related to the HEI system, a reorganized model is presented (Figure 1), which includes a new dimension, following Lozano's suggestion, plus a visual representation to illustrate the relationships that exist among its parts.

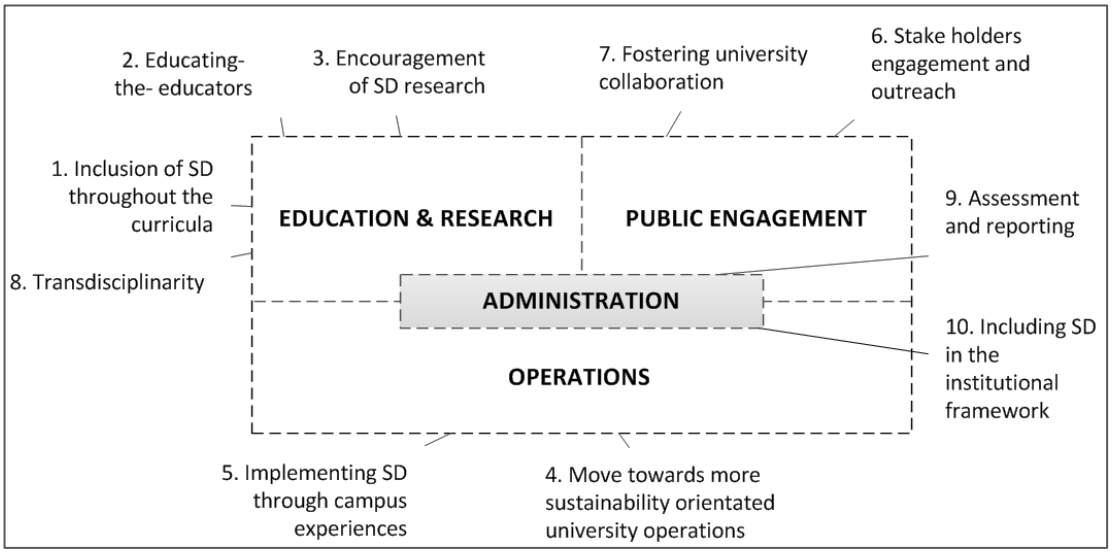

Figure 1: The HEI system.
Source: Prepared by the author

The base of the model is assigned to the **operations** dimension which supports all the institutional activities, including all resource consumption and human resource management processes. The upper level is related to the main channels through which the institution influences society, and considers curricular and research processes under the **education & research** dimension and community outreach under the **public engagement** dimension. Finally, at the center of the model is the **administration** dimension, which covers all policy, strategies and high level decisions influencing all the other dimensions. To illustrate how the sustainability elements of HEI can be related to this model, they are represented as linked to their respective dimensions in the diagram (Figure 1).

It is important to highlight that these dimensions are interrelated, and that the sustainability effort require for increasingly integrated functions between them, as Cortese argues:

"The educational experience of graduates must reflect an intimate connection among curriculum and research; understanding and reducing any negative ecological and social footprint of the institution; and working to improve local and

regional communities so that they are healthier, more socially vibrant and stable, economically secure, and environmentally sustainable" (Cortese, 2003).

1.3.2. Comparing new assessment approaches

There are three main approaches for assessing and reporting sustainability in organizations; accounts, narrative assessments and indicator-based. Each of them have strengths and weaknesses, but "in general indicator-based assessments have an overall higher performance and are more easily measurable and comparable than the other two approaches because they tend to be more objective" (Lozano, 2006b).

It is important to have in mind that even if the process of selecting a set of indicator for assessing sustainability is conducted in an objective manner, there is always a meaning behind the selection reflected on what is valued enough to be measured (Rencoret, 2011; Shields, Šolar, & Martin, 2002).

Four recent or new indicator-based assessment tools were chosen for comparison, because of their originality and popularity within the international context. Two of these tools correspond to a modification of other assessment or reporting methodologies, and two have been created specifically as sustainability assessment tools for HEI.

The tools were analyzed considering the attributes proposed by Shriberg (Shriberg, 2002), and compared with respect to their complexity, weighting method, mayor weaknesses and strengths, and potential field of application (Table 1).

According to Shriberg the "ideal" cross-institutional sustainability assessment tools have the following attributes (Shriberg, 2002):

- **They identify important issues**: "Address contextually appropriate issues of major importance to campus environmental, social and economic efforts and effects".
- **They are calculable and comparable**: Must be based on measurement methods that are "flexible enough to capture organizational complexities and differences", yet specific and comparable.
- **They move beyond eco-efficiency**: An eco-efficiency focus is narrowed to "material utilization, while sustainability indicators stress issues at the nexus of the environment, society and economy with the goal of no negative impacts".
- **They measure process and motivations**: Considering that sustainability is a process of continual improvement, sustainability assessment tools should cover "dynamic processes and motivations—including direction, strategy, intent and comprehensiveness—as well as present impacts."
- **They stress comprehensibility**: "Sustainability assessment tools must be comprehensible to a broad range of stakeholders. Thus, analysts must develop mechanisms for reporting that are verifiable and lucid".

The **Graphical Assessment of Sustainability in Universities** (GASU) model proposed by Lozano is based on an adaptation of the Global Report Initiative (GRI) methodology. GASU adds an educational dimension to the social, economic and environmental dimension ones, followed by 8 categories, 43 sub-categories (aspects) and 126 indicators. The model allows to generate a complete image of the institution's performance covering all important issues, but it requires large amounts of data to compile all indicators, which makes it difficult to apply, and also "complicates longitudinal comparisons and benchmarking" (Lozano, 2006b). The GASU model is an useful method to facilitate the understanding and communications regarding information compiled in a sustainability report, allowing to get a visual idea of the performance of the HEI, relying on the use of AMOEBA graphs (Ten Brinks, Hosper, & Colijn, 1991).

The **Three Dimensional University Ranking** (TUR) model proposed by Lukmann, seeks to "improve the methodology and indicators of the existing ranking tables" for Universities, incorporating the environmental dimension (Lukman et al., 2010). The model is divided in three dimensions, and considers a total of 15 indicators. The proposal introduces the use of the Analytical Hierarchy process (Saaty, 1987), to establish weights for the selected indicators in a participative and expert driven manner. This tool is relatively simple to apply and could be adequate for international benchmarking related to sustainability in HEI, considering that it works under the same logic of other international university rankings, such as Arwu (ARWU, 2012) and QS (QS World University Rankings, 2012). On the other hand, since it simplifies the sustainability dimension to a set of five indicators, TUR might not be appropriate if a more comprehensive sustainability assessment is needed.

The **Sustainability Tracking and Assessment Rating System** (STARS) it is an initiative of the Association for the Advancement of Sustainability in Higher Education (AASHE). It has become one of the most comprehensive and popular tools being used today (Saadatian & Salleh, 2011). STARS is divided in three main categories, 17 sub-categories and considers a total of 67 indicators (AASHE, 2011). The model is being continually improved, considering an open consultation process. The are two main impediments for applying this tool, in first place that it was initially designed for an advanced context, the United States and Canada (García, 2010), where sustainability efforts have a long history of success, and second that requires the active participation of the institutions in order to acquire all the necessary information. STARS is useful for supporting the sustainability journey of HEI, working as a route map where the experiences of more advanced institutions are presented through the proposed indicators rationale and criteria.

The **Green Metric (GM)** ranking is an initiative of the Univesitas Indonesia, launched in 2010. The aim of this tool is to generate an alternative international ranking that enables the assessment of "Green Campus and Sustainability in the Universities all over the world" (Universitas Indonesia, 2012). The tool is divided into 5 dimensions and considers a total of 34 indicators. It has a clear eco-efficiency focus, failing to consider other key aspects of sustainability such as diversity and equity performance.

Table 1: A comparison of four new assessment tools

Tool	Complexity	Weighting method	Mayor strengths	Mayor weakness	Potential use
GASU	**High** 5 levels 126 indicators	- Author proposal - Fully explained	- Covers all important issues - Uses AMOEBA graph to facilitate understanding.	- Requires large amount of data. - Hard to apply in HEI without sustainability GRI reports on sustainability	-Internal, facilitating comprehension and communication of data presented in GRI reports on sustainability.
TUR	**Low** 3 levels 15 indicators	- Expert driven - Based on the AHP	-Simplicity and resonance with university rankings tools. -Use of "triangle" graph to facilitate understanding	- Oversimplified sustainability issues within five indicators	-International. Rapid assessment of university.
STARS	**High** 4 levels 67 indicators	- Author proposal - Partially explained	- Detailed rationale methodology for calculating indicators. - Active support from AASHE	- Designed for an advanced context.	-For comparison of advanced HEI on sustainability. - Guideline for beginners.
GM	**Medium** 3 levels 34 indicators	- Author proposal - Not explained	- Active support from Universitas Indonesia	- Narrowed to eco-efficiency measures	-International benchmarking related to environmental efforts in HEI

Source: Prepared by the author

The following conclusions can be extracted from the revision and comparison of the selected tools:

- The weighting method can have a significant impact on the final rank obtained through the application of any tool (Lukman et al., 2010; Mayer, 2008), so is important for the user to understand its rationale and justification. Although the GASU, STARS and GM tools do explain their weighting structure they do not present any justification for it. In the case of the TUR tool, they use an expert driven approach based on the AHP method, which has the advantage of allowing continual improvement by repeating the consultation process.

- Although graphical display clearly facilitates the comprehension of results only the TUR and GASU tools cover this aspect. In the case of TUR the "triangle method" is used, which allows a clear comparison of HEI with regard to the final rank and second level dimensions in the same graph. For a detailed comparison the GASU proposal based on the AMOEBA graph could be more appropriate.

- When compared with respect to their adaptability to different contexts, the GM and STARS tools are more rigid considering that without a guide for assigning weights it is just not possible to add or remove indicators. In the case of GASU, since is based on the GRI methodology, it allows the incorporation of new indicators based on their materiality to the institution being assessed. The TUR tool is explicitly described as flexible (Lukman et al., 2010), enabling the inclusion of additional indicators, subject to repeating the AHP process with the new set of indicators.

- All the tools previously compared have advantages, such as appropriate coverage of sustainability themes, adequate display of results, and detailed explanation of the methodology. But none of them seems to be

appropriate to assess HEI within different implementations stages and data availability scenarios.

1.4. Methodology

In order to create an assessment model that is adaptable to different contexts but at the same time is able to establish common ground criteria, a methodology based on a process of four-step process (Figure 2) was followed, going from a general to context-specific application:

1) **Structuring the problem** in a four level hierarchy, starting with the goal that we want to asses, followed by assessment criteria, sub-criteria, and on the final level a set of potentially useful indicators conceived to cover all sub-criteria.
2) **Building weighting criteria**, on the basis of an international consultation in order to integrate a wide spectrum of experiences and opinions, using the analytic hierarchy process (AHP) (Saaty, 1987).
3) **Contextual calibration,** with regard to the selection of a viable set of indicators based on available information, and determining the weight of the indicators on the basis of a local consultation using the AHP.
4) **Calculating and showing results,** considering the process of normalization and aggregation of data to obtain a final rank, and the selection of appropriate graphic support for visual evaluation of the institutions.

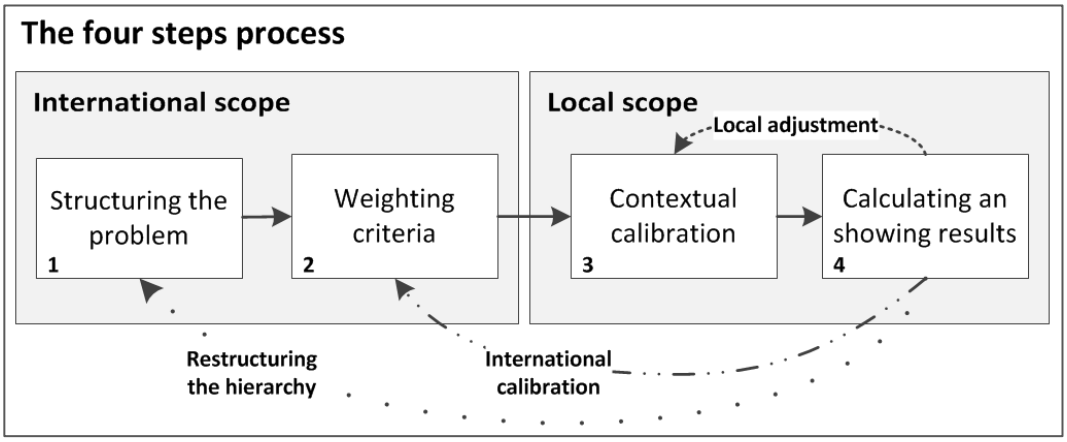

Figure 2: Adaptable method for creating the assessment model
Source: Prepared by the author

1.4.1. Structuring the problem: assessment hierarchy

The assessment model was constructed in order to properly cover all the elements highlighted by the sustainability in HEI declarations mentioned before, in relation to the university system presented on Figure 2.

As a result a four level hierarchy was proposed (Figure 3), with the overall goal of implementing sustainability in a HEI in the first level (A), followed by three criteria on the second level: Institutional commitment (B_1), setting an example (B_2) and encouragement for sustainability (B_3). In the third level are nine sub-criteria (C_j), and in the fourth a list of 25 indicators that could be applied in the Chilean context considering available data (I_k).

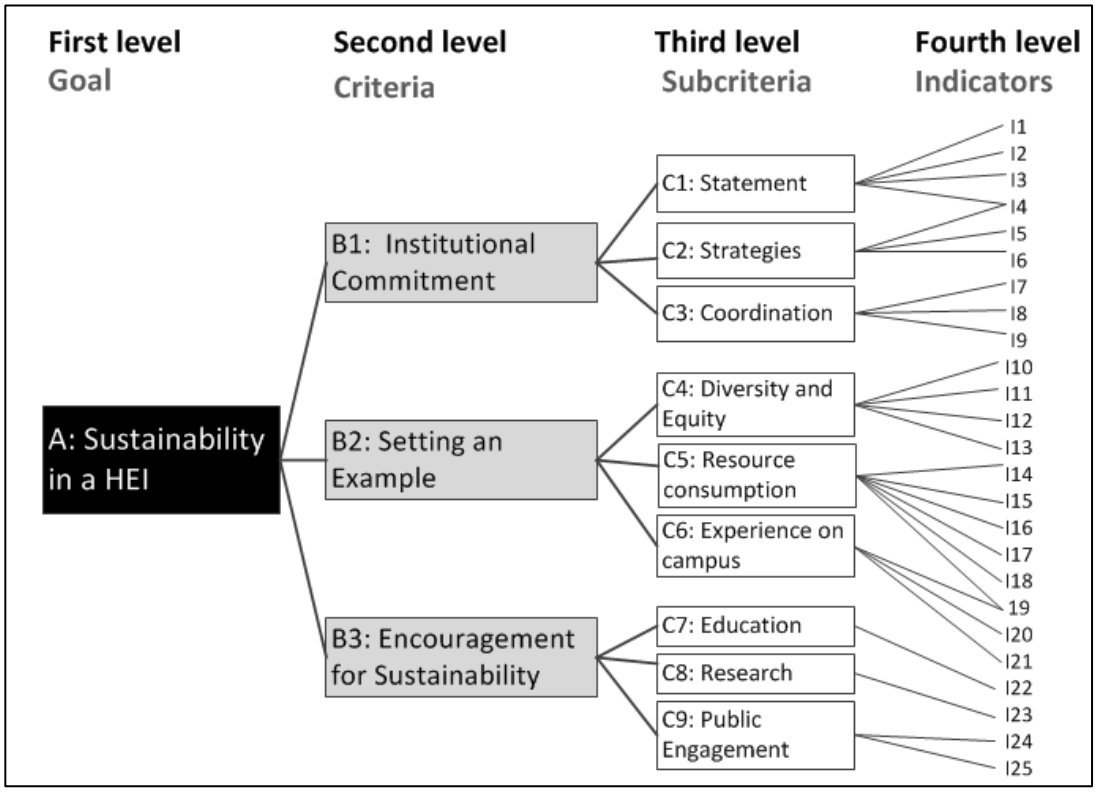

Figure 3: Four level hierarchy for sustainability assessment in a HEI
Source: Prepared by the author

a) The Institutional Commitment Criterion (B_1)

Stronger assessment tools consider "systemic changes, which include incentive and reward structures, mission and goals statements, procedures, annual reports and other organizational decision-making processes" (Shriberg, 2002). The institutional commitment criterion covers this aspects, aiming to assess the existence of symbolic, political and management platforms to create and enhance the necessary efforts to implement sustainability in the HEI context. It corresponds to the central part of the HEI system presented on Figure 1.

To assess this criterion, three sub-criteria are proposed:

- Statement (C_1), which recognizes the existence of formal declarations and public statements made by the institution related to sustainability in higher education.
- Strategies (C_2), which aims at recognizing the incorporation of sustainability in the institutional planning and evaluation.
- Coordination (C_3), which recognizes the existence of entities in charge of coordinating and promoting the efforts regarding sustainability.

b) The Setting an Example Criterion (B_2)

Although the main activities of HEI are research and education, it is important to consider that if "students hear about global responsibility while being educated in institutions that often invest their financial weight in the most irresponsible things… the lessons being taught are those of hypocrisy and ultimately despair" (Orr, 1991). Therefor the internal institutional practices should be a key element of the sustainability effort in all institutions, covering social, environmental aspects, and cross-functional actions that integrate teaching, research and operation activities (Cortese, 2003; Shriberg, 2002). The B2 criterion corresponds to the operational base of the HEI system presented in Figure 1.

To assess this criterion, the present study considers three sub-criteria:

- Diversity and equity (C4), which aims to assess the diversity and inclusiveness of the institution, covering issues such as wage schemes, equal gender opportunities and access for students from low socioeconomic backgrounds.
- Resource consumption (C5), which aims to assess the environmental performance of campuses and measures being taken to improve it, covering issues such as energy and water consumption and waste management.
- Experience on campus (C6), covers the efforts being taken to increase the perception and participation with the sustainability effort in day to day

activities on campus, covering issues such as internal communications, community training programs and events.

c) The Encouragement for Sustainability Criterion (B_3)

Higher education institutions can contribute to sustainable development in many ways, but especially through the influence of their graduate students, the innovations and discussions catalyzed by research activities, and the promotion of sustainability within the local and international community through engagement activities. B3 corresponds to the upper part of the HEI system presented on Figure 1, covering the education, research and public engagement dimensions.

To assess this criterion, the study considers three sub-criteria:

- Education (C7), which aims at recognizing the efforts of training students with the necessary skills to contribute to the construction of a more responsible, equitable and environmentally concerned society.
- Research (C8), which aims at recognizing the promotion of research that contributes to the general comprehension of difficulties regarding sustainable development, as well as new technologies, strategies and approaches that enable people to confront these problems and create new opportunities.
- Public engagement (C9), which aims at recognizing the efforts being made to connect institutional activities and the challenges beyond campuses concerning sustainable development.

1.4.2. Selecting a set of indicators

An initial list of potential indicators was obtained from six different existing assessment tools (AASHE, 2011; Lozano, 2006b; Lukman et al., 2010; Roorda, 2001; ULSF, 2001; Universitas Indonesia, 2012). Following this the indicators were classified according to the proposed sub-criteria, and reduced by elimination

of duplicates and filtering based on the principles proposed by Hezri (Hezri, 2004). Starting by eliminating indicators that were too specific and giving preference was given to those covering key issues based on the robustness principle, and then eliminating indicators that were difficult to assess based on the longevity principle, in order to propose a set of indicators that could be periodically audited. Finally based on the relevance principle (Hezri, 2004), a fundamental part of the process is selecting a set of indicators that considers local priorities and data availability constrains.

To incorporate local priorities from the Chilean context, a group of eight experts were asked to prioritize against every sub-criterion which indicators would be preferable to assess the sustainability efforts in the local context, resulting a prioritized list of 55 indicators. Then the list was compared against available data, considering four Chilean HEI with sustainability reports or equivalent. As a result, a final list of 25 indicators that were feasible to calculate was finally obtained.

1.4.3. Using the AHP method

To calculate a final index using the proposed hierarchy it is necessary to establish the relative importance of criteria, sub-criteria and indicators. This is very difficult to determine with sufficient accuracy (Afgan, 2004; Krajnc & Glavič, 2005), because we deal with complex phenomena, where in many cases there is no simple and objective comparison among the issues being assessed. To overcome this problem an expert consultation was conducted and processed using the analytic hierarchy process (Saaty, 1987). This method has been used to solve many complex decision making and prioritizing problems (Vaidya & Kumar, 2006), including specific applications on the field of sustainable assessment (Krajnc & Glavič, 2005; Lukman et al., 2010; Singh, Murty, Gupta, & Dikshit, 2007).

The AHP method decomposes the problem in a hierarchy of criteria, sub-criteria and alternatives (Lukman et al., 2010), then the various criteria at a particular level of the hierarchy are subsequently compared pair-wise with respect to the corresponding criteria in the immediate upper level by a group of experts.

As an example, for the proposed assessment hierarchy on Figure 3, a pairwise comparison for the second level with respect to the first level, would be comparing the relative importance of the setting an example criterion (B2) and the encouragement for sustainability criterion (B3), in assessing the goal of internalizing sustainability in a higher education institution (A).

Once all pairwise comparisons are obtained, they are aggregated by geometric mean (Wu & Lin, 1998), and organized on a judgmental (n x n) matrix D:

$$\mathrm{D} = \begin{bmatrix} 1 & d_{12} & \cdots & d_{1n} \\ 1/d_{12} & 1 & \ldots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/d_{1n} & 1/d_{2n} & \ldots & 1 \end{bmatrix} \quad (1,1)$$

Where each element d_{ij} correspond to the aggregated pair-wise comparisons between criteria i and j. This is a positive reciprocal matrix, where the diagonal $d_{ii} = 1$ and $d_{ij} = (1/d_{ji})$, for i, j = 1,…,n.

The priorities are obtained by finding and normalizing the principal eigenvector of the matrix D, correspondent to its largest eigenvalue λ_{max}, by solving the following equation:

$$W(D - \lambda_{max}\, I) = 0 \quad (1,2)$$

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \cdot \\ w_n \end{bmatrix} \quad (1,3)$$

Where W, is the eigenvector or raw vector of priorities of the judgmental matrix D, and I corresponds to an identity matrix of order n.

In order to obtain the weights, the eigenvector needs to be normalized as follows:

$$\overline{W} = \begin{bmatrix} w_1 / \sum_{k=1}^{k=n} w_k \\ w_2 / \sum_{k=1}^{k=n} w_k \\ \vdots \\ w_n / \sum_{k=1}^{k=n} w_k \end{bmatrix} \quad (1,4)$$

A complete example of the calculation process is presented on Appendix A.

Once the judgmental matrix is obtained, its consistency can be estimated by a measure called the consistency ratio (C_R):

$$C_R = {C_I}/{R_I} \quad (1,5)$$

Where R_I is a random index for which Saaty (Saaty, 1987) provided values from randomly generated matrices (Table 2), and the C_I correspond to a consistency index for a matrix of order N defined as:

$$C_I = {(\lambda_{max} - N)}/{(N-1)} \quad (1,6)$$

Consistency ratios of 0.1 or less are generally consider acceptable, but for matrices of size four and three the suggested thresholds are 0.08 and 0.05 respectively. If the value exceed this threshold the judgments might not be reliable and should be solicited again (Berrittella, Certa, Enea, & Zito, 2007).

Table 2: Average consistencies of random matrices ($\mathbf{R_I}$ values)

Size	1	2	3	4	5	6	7	8	9	10
R_I	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

1.4.4. Stakeholder consultation

The AHP method requires for the consultation of experts, which for purposes of this study were defined as individuals who have proven experience in the implementation of sustainability in HEI. The process of consultation followed three steps described as follows:

a) Defining the sample

A list of HEI with public recognition, internal or external, of being in the process of implementing sustainability within their institutional practices was built. For this two international and two Chilean sources of information were used, selecting:

- HEI with gold rank in the STARS ranking (AASHE, 2012).
- HEI in the first twenty positions of the GreenMetric ranking (Universitas Indonesia, 2012).
- Chilean HEI which signed the "Sustainable Campus Protocol" (MMA, 2009).
- Chilean HEI which publicly declared counting with some kind of sustainability coordination.

After the selection of the HEI, proceeded the collection of contact information of their sustainability managers, considering only those who were explicitly presented as sustainability coordinators or equivalent either by the title or for the description of their responsibilities, obtaining a final list of 112 experts.

b) Designing the survey

The consultation processes were conducted by sending a survey with pair-wise comparison to the experts (Appendix B. International survey). In order to facilitate the consultation, they were asked to express their preferences based on a 4 point scale (Table 3), to transform verbal judgments into numerical quantities, adapted from the one proposed by Saaty (Saaty, 1987). The adaptation was performed with

the aim of simplifying the questions asked to the experts so that they were easily answered in a short period of time.

Table 3: Adaptation from Saaty's verbal scale
Source: Prepared by the author

Verbal Scale	Equally important	Slightly more important	More important	Significantly more important
Numerical scale	1	3	6	9

c) Administrating the survey

Two consultations were made, starting by an international consultation to establish weights for criteria and sub-criteria of the proposed hierarchy, obtaining 23 answers from various countries (UK, Sweden, Ireland, USA, Canada, Chile), and a similar a local consultation to establish the indicators weights on a local context.

Both consultation processes results showed satisfactory consistency ratios. For matrices of order 3 the maximum obtained C_R was 0.032 (<0.052), for matrices of order 4 it was 0.032 (<0.089) and for matrices of order 6 it was 0.049 (<0.1).

d) Aggregating weights

Once obtained the weights for each level they were aggregated in order to obtain the final weights of the indicators with respect to the goal A as follows:

$$w(I_k)_A = w(B_i)_A \sum_{ij}^{n} \left[w(I_k)_{C_j} \, w\left(C_j\right)_{B_i} \right] \qquad (1,7)$$

Where $w(I_k)_A$ is the weight of indicator I_k with respect to the goal A, $w(B_i)_A$ the weight of criterion B_i with respect to goal A, $w\left(C_j\right)_{B_i}$ the weight of sub-criterion C_j with respect to criterion B_i and $w(I_k)_{C_j}$ the weight of the indicator I_k with respect to sub-criterion C_j.

1.4.5. Calculating final indicator values

Indicators might be based on quantitative or qualitative data. So to adequately process this information and estimating the final value of the indicators the following grading rules are proposed and used in this research.

For qualitative information the user can grade each indicator by applying a verbal rating scale such as the one proposed by Lozano, with five different choices, 0 – 4, where each correspond to (Lozano, 2006b):

0. There is a total lack of information for the indicator, it is non-existent.
1. The information presented is of poor performance.
2. The information presented is of regular performance.
3. The information presented is considered to be of good performance.
4. The information indicates excellent performance.

It should be noted that the performance is dependent of the indicator being assessed, so the verbal rating should always be understood separately under each situation.

For quantitative information there are three kinds of indicators: binary, total amount, and performance. Each binary indicators has only two possible outcomes; it does or does not meet the criteria, to which grades 1 and 0 are assigned, respectively. Total amount indicators correspond to those where the raw data is sufficient for comparison. Finally performance indicators require information to be compared against the relative size or impact of the HEI, to avoid contextual distortions as much as possible. For this, it becomes necessary to gather general information to build a base line of the HEI, such as:

- People: number of students, number of workers (ideally as equivalent full-time person time load), total amount of people in high level governance committees.
- Area: Total gross floor area.

- Curricular: Total number of programs and courses.
- Web: Total presence on the web of the HEI.
- Research: Total number of research papers.

1.4.6. Normalization and aggregation of results

Considering that the indicators may be expressed in different units and probably include a wide range of data, to be able to aggregate them the following normalization method was used :

$$I_{N,k}^{+} = \left(I_k - I_{min,k}\right) \Big/ \left(I_{max,k} - I_{min,k}\right) \quad (1,8)$$

$$I_{N,k}^{-} = \left(I_{max,k} - I_k\right) \Big/ \left(I_{max,k} - I_{min,k}\right) \quad (1,9)$$

Where $I_{max,k}$ and $I_{min,k}$ correspond to the maximum and minimum values obtained for the indicator k. $I_{N,k}^{+}$ is the normalized indicator k when a higher value is consider to be better and $I_{N,k}^{-}$ the opposite.

Once all data is normalized the final result are obtained applying the next equations:

$$C_j = \sum_{jk}^{n} w(I_k)_{C_j} I_{N,k}^{+} + \sum_{jk}^{n} w(I_k)_{C_j} I_{N,k}^{-} \quad (1,10)$$

$$B_i = \sum_{ij}^{n} w\left(C_j\right)_{B_i} C_j \quad (1,11)$$

$$A = \sum_{k}^{n} w(I_k)_A \; I_{N,k}^{+} + \sum_{jk}^{n} w(I_k)_A \, I_{N,k}^{-} \quad (1,12)$$

Where C_j is the performance for the sub-criterion j, B_i the performance for criterion i and A the final overall rank of the HEI.

To facilitate communication of results, the triangle method was used following the example of the TUR model, which allows illustrating the final rank and second level results in the same graph. And the AMOEBA graph for the third level result, allows a more detailed comparison among HEI with regard to sub-criteria results.

1.5. Results

The main results of the study are: An adaptable model for assessing sustainability in HEI, and the first inquiry with regard to the advancement of sustainability in the Chilean context.

1.5.1. Adaptable Model to Assess Sustainability in HEI (AMAS)

As a result of the application of the four step process, mentioned in Section 1.4, the Adaptable Model for Assessing Sustainability in HEI (AMAS) was built.

a) Adaptation possibilities

The model can be modified in order to be used in different contexts or updated depending on user needs, as illustrated on Figure 2. The possible adaptations are:

- Local adjustment:
  Repeat from the third step if recalibration of weights of indicators is needed; because of new data availability allows the use of new indicators, or in order to extend the local consultation to more stakeholders.
- International calibration
  Repeat from the second step in order to improve the criteria and sub-criteria weighting scheme, by extending the international consultation including more or new stakeholders.
- Restructuring the hierarchy:

Repeat from the first step in order to consider new approaches in the sustainability assessment field that could affect the proposed theoretical framework of the model.

b) Weighted hierarchy

As a result of the full application of the four step process, a full model was obtained for the application in the Chilean context. Although it could be adapted to any other context considering results from levels two and three, obtained from the international consultation process.

Table 4: Criteria and sub-criteria weights

B_i Criterion	$w(B_i)_A$	C_j Sub-criterion	$w(C_j)_{B_i}$	$w(C_j)_A$
B_1 Institutional commitment	0.3614	C_1 Statement	0.1879	0.0679
		C_2 Strategies	**0.4558**	0.1647
		C_3 Coordination	0.3564	0.1288
B_2 Setting an example	**0.3816**	C_4 Diversity and equity	0.1593	0.0608
		C_5 Resource consumption	**0.5025**	0.1917
		C_6 Experience on campus	0.3382	0.1291
B_3 Encouragement for sustainability	0.2570	**C_7 Education**	**0.4677**	0.1202
		C_8 Research	0.2842	0.0730
		C_9 Public engagement	0.2481	0.0638

Source: Prepared by the author

The resulting weighting scheme for criteria and sub-criteria, obtained from the international consultation is presented in Table 4 and the final indicator's weights, adding the local consultation in Table 5.

According to these results the **setting an example** criterion (B2) is the most important closely followed by the **institutional commitment** criterion. On the sub-criteria level, the **strategy** (C2), **resource consumption** (C5) and **education** (C7) sub-criteria are the most important to the corresponding criterions.

On the lower level the most important indicators are: **sustainability related programs** (I22), followed by **sustainability in the strategic institutional plan** (I4) and the **recycling program coverage** (I19), representing together 32.8% of the total weight.

Table 5: Indicator's weight

I_k	Indicator	C_j	$w(I_k)_{C_j}$	$w(I_k)_{B_1}$	$w(I_k)_{B_2}$	$w(I_k)_{B_3}$	$w(I_k)_A$
I_1	Sustainability sign commitments	C_1	0.1075	0.0202	-	-	0.0073
I_2	Authority's declarations related to sustainability	C_1	0.0690	0.0130	-	-	0.0047
I_3	Sustainability in the institutional vision and mission	C_1	0.3440	0.0646	-	-	0.0234
I_4	**Sustainability in the institutional strategic plan**	**C_1** **C_2**	**0.4795** **0.4934**	**0.3150**	**-**	**-**	**0.1138**
I_5	Sustainability plan	C_2	0.3421	0.1559	-	-	0.0564
I_6	Sustainability report	C_2	0.1645	0.0750	-	-	0.0271
I_7	Sustainability coordination	C_3	0.7115	0.2536	-	-	0.0916
I_8	Environmental management coordination	C_3	0.1256	0.0448	-	-	0.0162
I_9	Social responsibility coordination	C_3	0.1629	0.0581	-	-	0.0210
I_{10}	Women in high-level governance positions	C_4	0.1554	-	0.0247	-	0.0094
I_{11}	Students from low socioeconomic background	C_4	0.4803	-	0.0765	-	0.0292
I_{12}	Average career cost	C_4	0.1153	-	0.0184	-	0.0070
I_{13}	Minimum wage	C_4	0.2490	-	0.0397	-	0.0151
I_{14}	Energy consumption	C_5	0.2899	-	0.1457	-	0.0556
I_{15}	Energy efficiency measures	C_5	0.0943	-	0.0474	-	0.0181
I_{16}	Water consumption	C_5	0.2306	-	0.1159	-	0.0442
I_{17}	Water efficiency measures	C_5	0.0772	-	0.0388	-	0.0148
I_{18}	Hazardous waste management	C_5	0.1154	-	0.0580	-	0.0221
I_{19}	**Recycling program coverage**	**C_5** **C_6**	**0.1927** **0.4481**	-	**0.2484**	**-**	**0.0948**
I_{20}	Sustainability web site	C_6	0.1331	-	0.0450	-	0.0172
I_{21}	Sustainability outreach campaigns	C_6	0.4188	-	0.1417	-	0.0541
I_{22}	**Sustainability related programs**	**C_7**	**1.0000**	**-**	**-**	**0.4677**	**0.1202**
I_{23}	Sustainability related research	C_8	1.0000	-	-	0.2842	0.0730
I_{24}	Sustainability related presence on the web	C_9	0.6500	-	-	0.1613	0.0414
I_{25}	Inter-Campus Collaboration on Sustainability	C_9	0.3400	-	-	0.0844	0.0217

Source: Prepared by the author

c) Indicators and rationale

Considering the grading rules stated on Section 1.4.5, the indicators obtained for the Chilean application are separated between qualitative and quantitative, and explained as follows.

Qualitative indicators:

I_3. Sustainability in the institutional vision and mission.

I4. Presence of sustainability in the institutional strategic plan.

I5. Sustainability report: Does it counts with a sustainability report? Does it cover all important issues?

I15. Energy efficiency measures: What efforts are being made to reduce energy consumption?

I17. Water efficiency measures: What efforts are being made to reduce water consumption?

I18. Hazardous waste management: What efforts are being made to minimize and safely dispose of all hazardous waste?

I19. Recycling program coverage: What efforts are being made to reduce waste a conserving resources by recycling and composting?

I20. Sustainability web site: Does it counts with a complete and dynamic sustainability web site?

I21. Sustainability outreach campaigns: What efforts are being made to spread and promote the sustainability principles within the institution's community through outreach campaigns?

I21. Sustainability outreach campaigns: What efforts are being made to spread and promote the sustainability principles within the institution community through outreach campaigns?

I25. Inter-Campus Collaboration on Sustainability: What efforts are being made to collaborate with other HEI on sustainability issues?

Quantitative indicators:

I_1. Sustainability sign commitments: Total number of commitments signed by the HEI.

I2. Declarations by authorities related to sustainability: Number of public declarations by the highest authority related to the sustainability efforts being made by the HEI.

I5. Sustainability plan: Does it counts with a sustainability plan? (Binary yes/no).

I7. Sustainability coordination: Does it count with some kind of sustainability coordination? (Binary yes/no).

I8. Environmental management coordination: Does it count with some kind of environmental management coordination? (Binary yes/no).

I9. Social responsibility coordination: Does it count with some kind of social responsibility coordination? (Binary yes/no).

I10. Proportion of women in high level governance committees: Women in high-level governance committees / total amount of people in high level governance committees.

I11. Students from low socioeconomic background: Students from fully and partially public funded schools/ total students.

I12. Average career cost: Average tuition for one year for all programs offered by the institution.

I13. Minimum wage: Paid by the institution.

I14. Energy: Total direct energy consumption (Electric, gas, diesel) / gross floor area.

I16. Water consumption: Total direct water consumption / (total students plus equivalent full-time person time load).

I22. Sustainability related programs: Total sustainability related programs / total programs.

I23. Sustainability related research: Total sustainability related research / total research

I24. Sustainability related presence on the web: Total sustainability related web presence of the HEI / total web presence of the institution.

1.5.2. Case study: Chilean Universities

The resulting assessment tool was applied to a group of five Chilean HEI (Table 6) selected considering availability of reliable data concerning their sustainability efforts, during the year 2010, being this the latest period where all five institutions counted with a sustainability report or equivalent.

The information was obtained mainly from institutional sustainability reports or equivalent (PUCV, 2010; Rencoret, 2011; UBB, 2010; UNAB, 2010; USACH, 2010), although in all cases it was necessary to obtain extra data from the institutional websites (I_2, I_4, I_{10}, I_{22}). Information related to average career cost (I_{12}) was obtained from local government web sources (CNED, 2010). In the case of the sustainability related research indicator (I_{23}), the information was obtained searching the Scopus database (Elsevier, 2012), and for the sustainability related presence on the web indicator (I_{24}), it was obtained searching in Google.

Table 6: Final results for five Chilean HEI

HEI	Rank	A	B_1	B_2	B_3
Pontificia Universidad Católica de Chile (PUC)	**1**	**0.552**	**0.338**	0.506	**0.922**
Universidad del Bío-Bío (UBB)	2	0.424	0.231	0.506	0.572
Pontificia Universidad Católica de Valparaíso (PUCV)	3	0.350	0.167	**0.593**	0.246
Universidad de Santiago de Chile (USACH)	4	0.261	0.324	0.269	0.161
Universidad Andrés Bello (UNAB)	5	0.214	0.112	0.078	0.559

Source: Prepared by the author

The results of the assessment are presented in Table 6, and Figure 4 using the "triangle method" (Li, Min, & Tan, 2005; Lukman et al., 2010) where it is possible to see the second level and the final rank results on the same graph.

The form of the triangles deliver important information related to the sustainability performance of the institution, where three main types of performances can be detected:

- **EF** (external focus institutions), when the ES angle is small and upward.
- **IF** (internal focus institutions), when the SE angle is upward.
- **S** (statement institutions), when the IC angle is upward.

The graph also shows the average performance of the institutions for the three assessment criterions, in order to observe which HEI are above and below.

In addition a more detailed graph is presented for the third level results (Figure 5), using an AMOEBA type of graph (Ten Brinks et al., 1991), which allows comparisons among the HEI on the sub-criteria level.

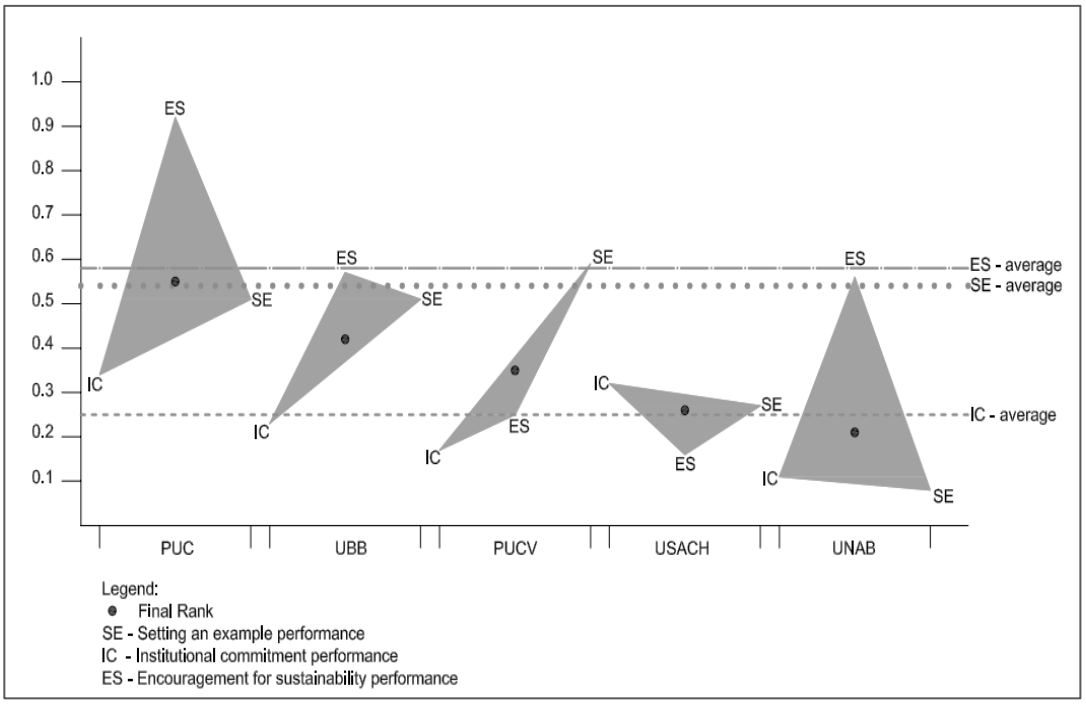

Figure 4: Final rank and second dimension results
Prepared by the author

The figure shows that PUC and UNAB have an **EF** performance, which could be interpreted as having higher external recognition of the sustainability effort compared to internal efforts being made to implement sustainability in the institutional practices. UBB has a similar type of performance showing more balance between the internal and external focus, which can be explained because of a better performance in both diversity and equity sub-criterions (Figure 5).

PUCV has an **IF** performance, with the highest rank on the **setting an example** criterion, but with a very low rank on the **encouragement for sustainability** criterion, mainly because of bad performance on the education sub-criterion.

USACH has an **S** performance, with the second highest value on the **institutional commitment** criterion. This could represent an institution at a starting point on the sustainability effort, that is, it would be just establishing the necessary platforms to enhance the process. In fact this was the only institution with some kind of sustainability coordination over the period covered by the study.

The results show the relative position of the HEI and particular aspects where institutions excel and those where they are lagging behind.

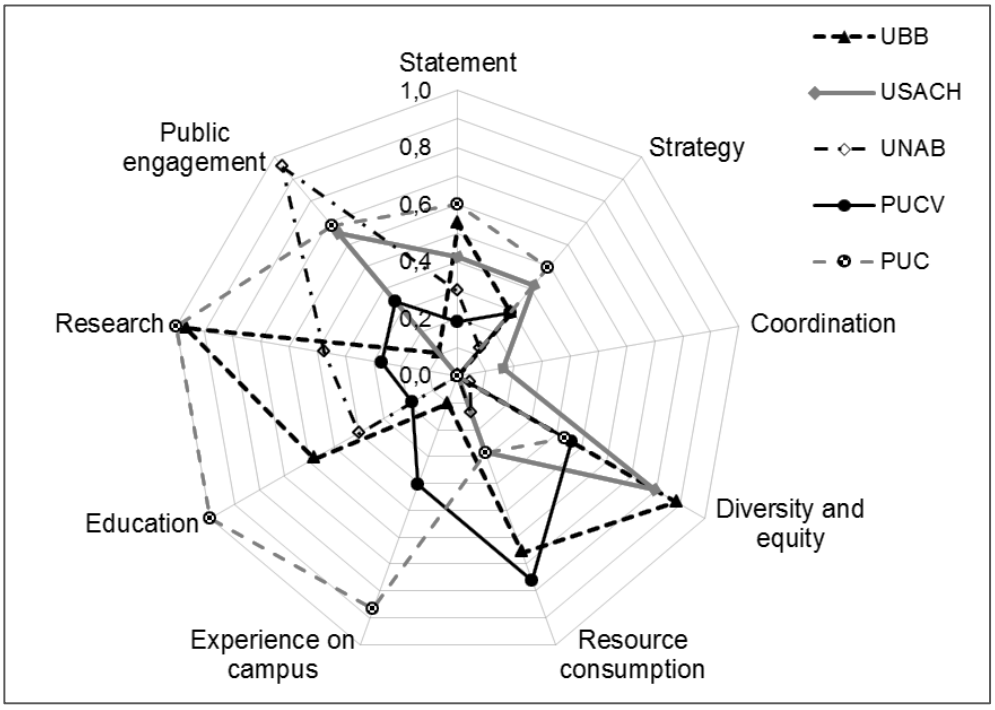

Figure 5: Detailed Sub-criteria results
Source: Prepared by the author

1.6. Conclusions

Upon revisiting the research questions and the hypothesis, several conclusions emerge.

a) For the first question: Is it possible to devise a model to evaluate and compare the implementation of sustainability for a broad range of higher education institutions?

- Considering the profound differences existing today, with regard to the sustainability efforts in HEI and data availability scenarios, it is very difficult to devise a working general model to evaluate the implementations of sustainability in a broad range of HEI. Probably that

is one of the reasons why proposals keep emerging in this regard, and why models have yet to have a success history at the international level.

- On the conceptual level, declarations and assessment models seem to be coherent, recognizing similar themes or key issues for the sustainability effort in HEI (Lozano et al., 2011; Shriberg, 2002). This establishes the possibility to count at least with a general assessment framework at the criteria level, securing flexibility at the indicator level.
- The literature review showed that existing assessment tools deliver most of the solutions needed to construct models applicable to different contexts, such as; methods for weighting criteria and indicators, aggregation and normalization of data, and graphical display of results. These features organized under the four step process presented in Figure 2, comprise a useful approach with a common framework at the criteria level, and explicitly flexible at in the indicator level, allowing the users to choose according to their context, and calibrating their weights on the basis of local consultation with experts.

b) For the second research question: What is the status of implementation of sustainability in Chilean HEI?

- Considering that only five HEI counted with some kind of centralize effort, either as a report or institutional declarations, to give notice of their interest and trajectory on the subject, it can be concluded that the sustainability effort in Chile is clearly at an early stage of development.
- The results of the full application of the developed model are coherent with the proposed hypothesis this because of two main reasons. In first place two of the HEI (PUC, UNAB) clearly showed an unbalanced better performance regarding the **encouragement for sustainability** criterion (ES) while the PUCV showed an unbalanced better performance regarding the **setting an example** criterion (SC). This corroborates, at

least for the group of five HEI, that the efforts remain specific. In second place, considering that integrative efforts have more possibilities or being ignited on the administration dimension (Figure 1), due to its transversality to all aspect of the higher education system, the fact that all HEI showed poor performance on the institutional commitment criterion shows that the integration between the operational and educational functions of the HEI remains unlikely.

c) Other conclusions

- The AHP method proved to be useful and relatively simple to implement for the purpose of having weights for criteria, sub-criteria and indicators. The method allows for continual improvements by expanding the consultation to more or new groups of experts. Also a sensitivity analysis could be applied to test the model, following the method proposed by Berrittella, comparing results through experiments varying the weights according to a process of geometric Brownian motion (Berrittella et al., 2007).
- The aggregation of weights is simple and allows for one indicator to be associated to different sub-criteria, which is useful considering that the sustainability effort require for increasingly integrated functions in HEI.
- The obtained weights for the sub-criteria level (Figure 6), showed that although the resource consumption themes were indicated as more important, similar to other assessment tools, a comparison with others sub-criteria showed that the strategy, experience on campus, coordination and education sub-criteria were also highly rated by experts.

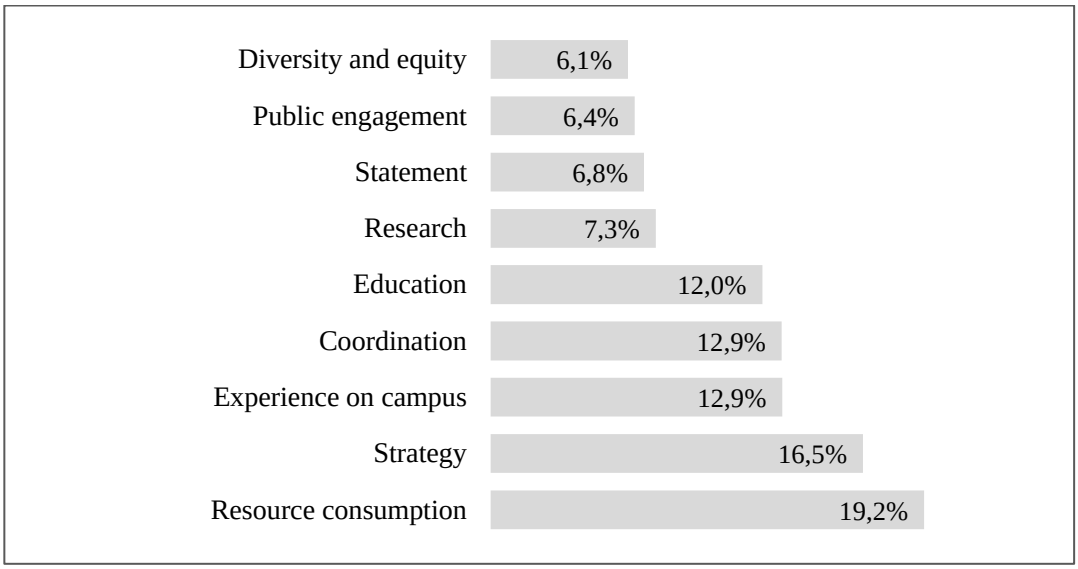

Figure 6: Predominance of sub-criterions
Source: Prepared by the author

1.7. Perspectives

The proposed model should be tested considering a bigger number of Chilean HEI, and aiming at covering more periods. This is feasible considering that more HEI are starting to report their sustainability efforts, which will add to the annual report actualizations of those HEI already considered in this study.

The proposed weighted hierarchy should be improved by extending the consultation process to a broader spectrum of expert and stakeholders.

2. ADAPTABLE MODEL FOR ASSESSING SUSTAINABILITY IN HEI

Paper Abstract

The goal of this paper is to introduce an Adaptable Model for Assessing Sustainability (AMAS) in higher education institutions (HEI) that enables the assessment of sustainability within different implementation stages and data availability scenarios.

The model's design was based on previous experiences in the field of sustainability in HEI, considering de revision of international declarations and four new assessment models.

The resulting AMAS model is based on a four level hierarchy, considering three main criteria; institutional commitment (**IC**), setting an example (**SE**), and encouragement for sustainability (**ES**). Nine sub-criteria and a set of 25 indicators were proposed considering the Chilean context.

In order to establish the weights of the proposed hierarchy, the analytic hierarchy process (AHP) was applied in two separate consultations; first an international consultation in order to establish weights for the criteria and sub-criteria levels, followed by a local consultation in the Chilean context to establish weights for the indicator level.

The results of the AHP on the international level, showed a preference for de **IC** and **SE** criteria, with **36.1%** and **38.2%** weights respectively, and less preference for the **ES** criterion with a **25.7%** weight.

The model is strongly dependent on experts' personal opinions, so it could be improved by repeating the process with a wider spectrum of stakeholders within the international and local communities depending of the intended application.

The resulting model enables the assessment of sustainability within different contexts while maintaining a universal methodological approach, which represents a valuable contribution considering that sustainability in HEI is a context-specific and rapid change issue.

Keywords

Assessment; sustainability in HEI; flexible model; AMAS; four step process.

2.1.Introduction

Sustainable development (SD), defined as "development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations" (WCED, 1987), represents a major challenge of the XXI century. In this context, education has been recognized as the best hope and most effective means in the quest to achieve it (UNESCO, 1997).

The United Nations declared the period 2005-2014 the Decade of Education for SD which established an international mandate to incorporate the principles, values and practices of sustainability in all aspects of the educational processes (UNESCO, 2005). At the university level, the mandate is to reach campus sustainability.

Higher Education Institutions (HEI) have a "moral responsibility to increase the awareness, knowledge, skills, and values needed to create a just and sustainable future" (Cortese, 2003), especially because they prepare "most of the professionals who develop, lead, manage, teach, work in, and influence society's institutions…" (Cortese, 2003).

It is important to consider that students learn from everything around them, including curricula, research, operations and outreach activities establishing a complex network of experiences that define the profile of graduates (Cortese, 2003; Orr, 1991). It follows then that the process of implementing sustainability needs to cover all the functions and activities of the HEI.

In order to confront this challenge the HEI "require methods of comparison to each other as well as to a vision of a sustainable college or university to ensure that they are moving in the right direction" (Shriberg, 2002). That vision has been in part recognized in a series of international declarations (e.g. Talloires, Abuja, Barcelona) which "provide guidelines or frameworks for HEI to better embed sustainability into their system" (Lozano et al., 2011). This vision needs to be complemented with

comprehensive assessment tools that facilitate this process “through identification of best practices and focusing campus efforts on continual improvement” (Shriberg, 2002).

Many tools have been developed in order to assess advancement towards sustainability in HEI. Shriberg analyzed eleven of those tools, which provided “valuable insight into essential attributes of sustainability in higher education” (Shriberg, 2002), “but do not permit comparison between campuses” (Lukman et al., 2010).

More recently, new tools have been developed. Establishing interesting proposals that integrate the sustainability assessment for HEI with other assessment and reporting methodologies. However, even though these tools have been applied to an increasing number of institutions, their impact remains low, focusing mainly in HEI from North America and Europe.

This paper presents a discussion related to four new approaches, followed by a proposal for an Adaptive Model of Sustainability Assessment (AMAS) based on a flexible framework, which allows continuous improvement and local calibration in order to facilitate the assessment process in a broader context, including countries where the effort to implement sustainability in HEI is at early stage of development.

2.1.1. A sustainability framework for HEI

International declarations of sustainability give us a vision of what kind of transformations are required to fulfill the goal of embedding sustainability in the system of higher education, from which the following elements have been highlighted in previous revisions (Lozano et al., 2011):

1. Inclusion of sustainability throughout the curricula in all disciplines;
2. ‘Educating-the-educators’ on how to educate their students in SD and help foster multiply effects;

3. Encouragement of sustainability research;
4. Move towards more sustainability orientated to university operations;
5. Implementing sustainability through campus experiences, by incorporating sustainability into the day-to-day activities in the university life experiences;
6. Stakeholder, e.g. public, governments, non-governmental organizations (NGOs) and businesses, collaborations, engagement and outreach;
7. Fostering university collaborations;
8. Transdisciplinarity;
9. Assessment and reporting;
10. Including sustainability in the institutional framework.

To comprehend how these themes and elements can be integrated in HEI, it is important to understand how this type of system works, and how it can be understood from a sustainability point of view. Cortese (2003) proposed a model of four interdependent dimensions: Education, Research, Operations and Community outreach (Cortese, 2003), to which Lozano added a fifth dimension named Assessment and Reporting (Lozano, 2006a). However, these dimensions only cover what the HEI do, without considering who is behind those practices and how they are related and performed (Rencoret, 2011). In order to clarify how the elements stated above can be related to the HEI system, a reorganized model is presented (Figure 7), which includes a new dimension, following Lozano's suggestion, plus a visual representation to illustrate the relationship that exist among its parts.

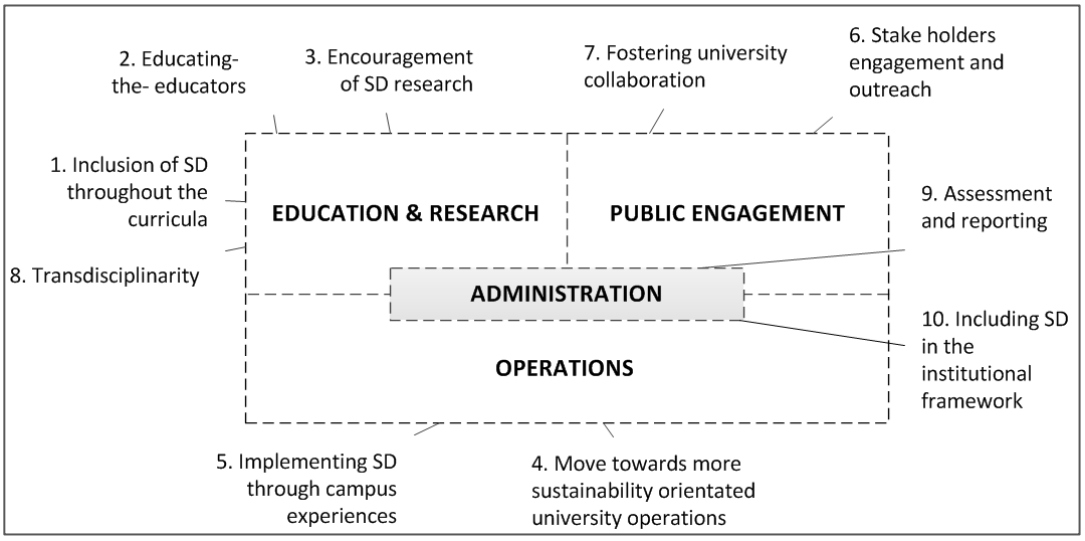

Figure 7: The HEI system.

The base of the model is assigned to the **operations** dimension which supports all the institutional activities, including all resource consumption and human resource management processes. The upper level is related to the main channels through which the institution influences society, and considers all academic activities under the **education & research** dimension and the community outreach under the **public engagement** dimension. Finally, at the center of the model, there is the **administration** dimension, which covers all policies, strategies and high level decisions influencing all the other dimensions. To illustrate how the sustainability elements of HEI can be related to this model, they are represented as linked to their respective dimensions in the diagram (Figure 7).

It is important to highlight that these dimensions are interrelated, and that the sustainability effort requires an incremental integration of functions in HEI system, as Cortese argues:

"The educational experience of graduates must reflect an intimate connection among curriculum and research; understanding and reducing any negative ecological and social footprint of the institution; and working to improve local and regional

communities so that they are healthier, more socially vibrant and stable, economically secure, and environmentally sustainable" (Cortese, 2003).

2.1.2. Comparing new assessment approaches

There are three main approaches for assessing and reporting sustainability in organizations: accounts, narrative assessments and indicator-based. Each of them has strengths and weaknesses, but "in general, indicator-based assessments have an overall higher performance and are more easily measurable and comparable than the other two approaches because they tend to be more objective" (Lozano, 2006b).

It is important to have in mind that even if the process of selecting a set of indicator for assessing sustainability is conducted in an objective manner, there is always a meaning behind the selection reflected on what is valuable enough to be measured (Rencoret, 2011; Shields et al., 2002).

Four recent or new indicator-based assessment tools were chosen for comparison, because of their originality and popularity within the international context. Two of these tools correspond to a modification of other assessment or reporting methodologies, and two have been created specifically as sustainability assessment tools for HEI.

The tools were analyzed considering the attributes proposed by Shriberg (Shriberg, 2002), and compared in relation to their complexity, weighting method, major weaknesses and strengths, and potential field of application (Table 7)
According to Shriberg the "ideal" cross-institutional sustainability assessment tools have the following attributes:

- **They identify important issues**: "Address contextually appropriate issues of major importance to campus environmental, social and economic efforts and effects".

- **They are calculable and comparable**: They must be based on measurement methods that are "flexible enough to capture organizational complexities and differences", yet specific and comparable.
- **They move beyond eco-efficiency**: An eco-efficiency focus is narrowed to "material utilization, while sustainability indicators stress issues at the nexus of the environment, society and economy with the goal of no negative impacts".
- **They measure process and motivations**: Considering that sustainability is a process of continual improvement, sustainability assessment tools should cover "dynamic processes and motivations—including direction, strategy, intent and comprehensiveness—as well as present impacts."
- **They stress comprehensibility**: "Sustainability assessment tools must be comprehensible to a broad range of stakeholders. Thus, analysts must develop mechanisms for reporting that are verifiable and lucid" (Shriberg, 2002).

The **Graphical Assessment of Sustainability in Universities** (GASU) model proposed by Lozano is based on an adaptation of the Global Report Initiative (GRI) methodology, adding an educational dimension to the social, economic and environmental ones, followed by 8 categories, 43 sub-categories (aspects) and 126 indicators. The model allows to generate a complete image of the institution's performance covering all important issues, but it requires large amounts of data to compile all indicators, which makes it difficult to apply, and also "complicates longitudinal comparisons and benchmarking" (Lozano, 2006b). GASU is a useful method to facilitate the understanding and communications regarding information compiled in a sustainability report, allowing to get a visual idea of the performance of the HEI, relying on the use of AMOEBA graphs (Ten Brinks et al., 1991).

The **Three dimensional University Ranking** (TUR) model proposed by Lukmann, seeks to "improve the methodology and indicators of the existing ranking tables" for Universities, incorporating the environmental dimension (Lukman et al., 2010). The model is divided in three dimensions, and considers a total of 15 indicators. The proposal introduces the use of the Analytical Hierarchy process (Saaty, 1987), to establish weights for the selected indicators in a participative and expert driven manner. This tool is relatively simple to apply and could be adequate for international benchmarking related to sustainability in HEI, considering that it works under the same logic of other international university rankings, such as Arwu (ARWU, 2012) and QS (QS World University Rankings, 2012). On the other hand, since it simplifies the sustainability dimension to a set of five indicators, TUR might not be appropriate if a more comprehensive sustainability assessment is needed.

The **Sustainability Tracking and Assessment Rating System** (STARS) is an initiative of the Association for the Advancement of Sustainability in Higher Education (AASHE). It has become one of the most comprehensive and popular tools used today (Saadatian & Salleh, 2011). STARS is divided in three main categories, 17 sub-categories and considers a total of 67 indicators (AASHE, 2011). The model is being continually improved, considering an open consultation process. There are two main impediments for applying this tool, in first place, it was initially designed for an advanced context, the United States and Canada (García, 2010), where sustainability efforts have a long history of success, and in second place, it requires the active participation of the institutions in order to acquire all the necessary information. STARS is useful for supporting the sustainability journey of HEI, working as a route map where the experiences of more advanced institutions are presented through the proposed indicators rationale and criteria.

The **Green Metric (GM)** ranking is an initiative of the Univesitas Indonesia, launched on 2010. The aim of this tool is to generate an alternative international ranking that enables the assessment of "Green Campus and Sustainability in the Universities all over the world" (Universitas Indonesia, 2012). The tool is divided into 5 dimensions and considers a total of 34 indicators. It has a clear eco-efficiency focus, failing to consider other key aspects of sustainability such as diversity and equity performance.

Table 7: Comparison between four new assessment tools

Tool	Complexity	Weighting method	Mayor strengths	Mayor weakness	Potential use
GASU	**High** 5 levels 126 indicators	- Author proposal - Fully explained	- Covers all important issues - Uses AMOEBA graph to facilitate understanding.	- Requires large amount of data. - Hard to apply in HEI without sustainability GRI reports on sustainability	-Internal, facilitating comprehension and communication of data presented in GRI reports on sustainability.
TUR	**Low** 3 levels 15 indicators	- Expert driven - Based on the AHP	-Simplicity and resonance with university rankings tools. -Use of "triangle" graph to facilitate understanding	- Oversimplified sustainability issues within five indicators	-International. Rapid assessment of university.
STARS	**High** 4 levels 67 indicators	- Author proposal - Partially explained	- Detailed rationale methodology for calculating indicators. - Active support from AASHE	- Designed for an advanced context.	-For comparison of advanced HEI on sustainability. - Guideline for beginners.
GM	**Medium** 3 levels 34 indicators	- Author proposal - Not explained	- Active support from Universitas Indonesia	- Narrowed to eco-efficiency measures	-International benchmarking related to environmental efforts in HEI

The following conclusions can be extracted from the revision and comparison of the selected tools:

- The weighting method can have a significant impact on the final rank obtained through the application of any tool (Lukman et al., 2010; Mayer, 2008), so is important for the user to understand its rationale and justification. Although the GASU, STARS and GM tools do explain their weighting structure they do not present any justification for it. In the case of the TUR tool, they use an expert driven approach based on the AHP method, which has the advantage of allowing continual improvement by repeating the consultation process.

- Although graphical display clearly facilitates the comprehension of results only the TUR and GASU tools cover this aspect. In the case of TUR the "triangle method" is used, which allows a clear comparison of HEI with regard to the final rank and second level dimensions in the same graph. For a detailed comparison the GASU proposal based on the AMOEBA graph could be more appropriate.

- When compared with respect to their adaptability to different contexts, the GM and STARS tools are more rigid considering that without a guide for assigning weights it is just not possible to add or remove indicators. In the case of GASU, since is based on the GRI methodology, it allows the incorporation of new indicators based on their materiality to the institution being assessed. The TUR tool is explicitly described as flexible (Lukman et al., 2010), enabling the inclusion of additional indicators, subject to repeating the AHP process with the new set of indicators.

- All the tools previously compared have advantages, such as appropriate coverage of sustainability themes, adequate display of results, and detailed explanation of the methodology. But none of them seems to be appropriate to assess HEI within different implementations stages and data availability scenarios.

2.2. Constructing the assessment model

In order to create an assessment model that is adaptable to different contexts but at the same time is able to establish common ground criteria, a methodology based on a process of four-step process (Figure 8) was followed, going from a general to context-specific application:

1) **Structuring the problem** in a four level hierarchy, starting with the goal that we want to asses, followed by assessment criteria, sub-criteria, and on the final level a set of potentially useful indicators conceived to cover all sub-criteria.
2) **Building weighting criteria**. On the basis of an international consultation in order to integrate a wide spectrum of experiences and opinions, using the analytic hierarchy process (AHP) (Saaty, 1987).
3) **Contextual calibration,** with regard to the selection of a viable set of indicators based on available information, and determining the indicator's weights on the basis of a local consultation using the AHP.
4) **Calculating and showing results,** considering the process of normalization and aggregation of data to obtain a final rank, and the selection of appropriate graphic support for visual evaluation of the institutions.

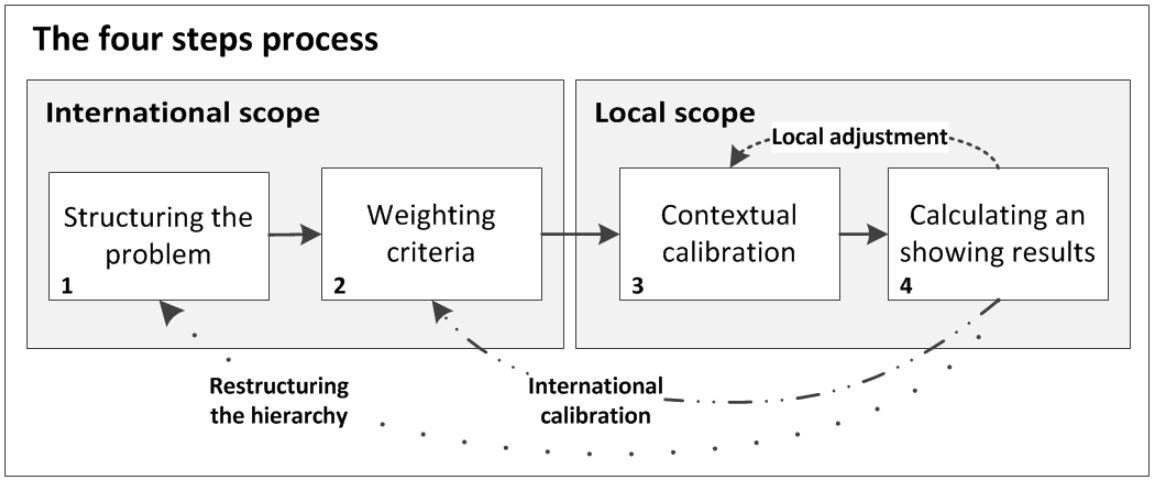

Figure 8: Adaptable method for creating an assessing model

2.2.1. Structuring the problem: assessment hierarchy

The assessment model was constructed in order to properly cover all the elements highlighted by the sustainability in HEI declarations mentioned before, in relation to the university system presented on Figure 7.

As a result a four level hierarchy was proposed (Figure 9), with the overall goal of implementing sustainability in a HEI in the first level (A), followed by three criteria on the second level: Institutional commitment (B_1), setting an example (B_2) and encouragement for sustainability (B_3). In the third level are nine sub-criteria (C_j), and in the fourth a list of 25 indicators that could be applied in the Chilean context considering available data (I_k).

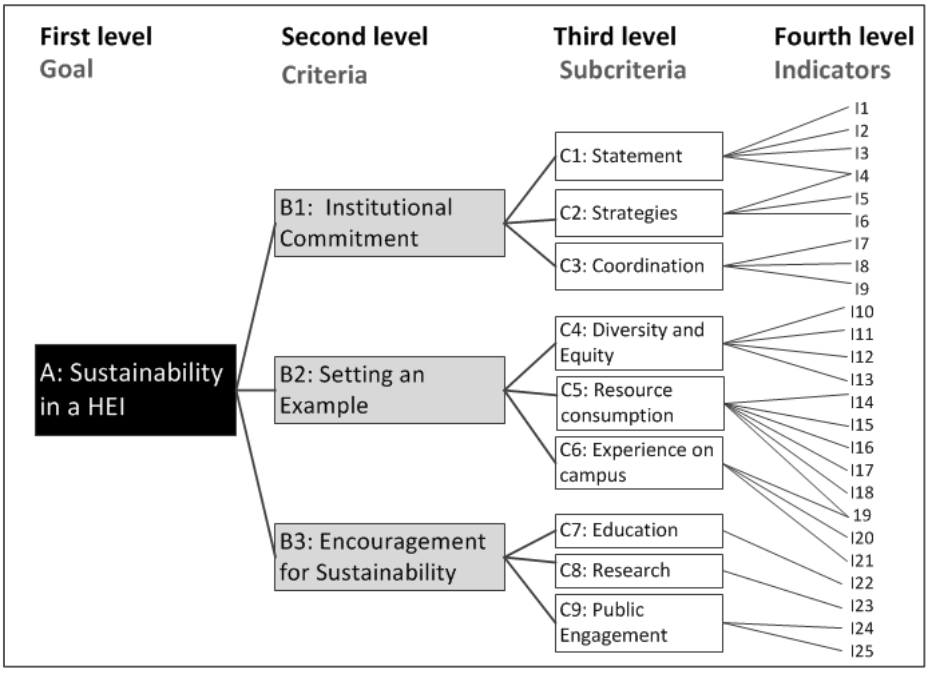

Figure 9: Four level hierarchy for sustainability assessment in a HEI

a) The Institutional commitment criterion (B_1)

Stronger assessment tools consider "systemic changes, which include incentive and reward structures, mission and goals statements, procedures, annual reports and other organizational decision-making processes" (Shriberg, 2002). The institutional commitment criterion covers this aspects, aiming to assess the existence of symbolic, political and management platforms to create and enhance the necessary efforts to implement sustainability in the HEI context. It corresponds to the central part of the HEI system presented on Figure 7.

To assess this criterion, three sub-criteria are proposed:

- Statement (C_1), which recognizes the existence of formal declarations and public statements made by the institution related to sustainability in higher education.
- Strategies (C_2), which aims at recognizing the incorporation of sustainability in the institutional planning and evaluation.
- Coordination (C_3), which recognizes the existence of entities in charge of coordinating and promoting the efforts regarding sustainability.

b) The Setting an example criterion (B_2)

Although the main activities of HEI are research and education, it is important to consider that if "students hear about global responsibility while being educated in institutions that often invest their financial weight in the most irresponsible things… the lessons being taught are those of hypocrisy and ultimately despair" (Orr, 1991). Therefor the internal institutional practices should be a key element of the sustainability effort in all institutions, covering social, environmental aspects, and cross-functional actions that integrate teaching, research and operation activities (Cortese, 2003; Shriberg, 2002). The B2 criterion corresponds to the operational base of the HEI system presented in Figure 7.

To assess this criterion, the study considers three sub-criterions:

To assess this criterion, the present study considers three sub-criteria:

- Diversity and equity (C_4), which aims to assess the diversity and inclusiveness of the institution, covering issues such as wage schemes, equal gender opportunities and access for students from low socioeconomic backgrounds.
- Resource consumption (C_5), which aims to assess the environmental performance of campuses and measures being taken to improve it, covering issues such as energy and water consumption and waste management.
- Experience on campus (C_6), covers the efforts being taken to increase the perception and participation with the sustainability effort in day to day activities on campus, covering issues such as internal communications, community training programs and events.

c) The Encouragement for sustainability criterion (B_3)

Higher education institutions can contribute to sustainable development in many ways, but especially through the influence of their graduate students, the innovations and discussions catalyzed by research activities, and the promotion of sustainability within the local and international community through engagement activities. B3 corresponds to the upper part of the HEI system presented on Figure 7, covering the education, research and public engagement dimensions.

To assess this criterion, the study considers three sub-criteria:

- Education (C_7), which aims at recognizing the efforts of training students with the necessary skills to contribute to the construction of a more responsible, equitable and environmentally concerned society.
- Research (C_8), which aims at recognizing the promotion of research that contributes to the general comprehension of difficulties regarding sustainable development, as well as new technologies, strategies and approaches that enable people to confront these problems and create new opportunities.

- Public engagement (C_9), which aims at recognizing the efforts being made to connect institutional activities and the challenges beyond campuses concerning sustainable development.

2.2.2. Selecting a set of indicators

An initial list of potential indicators was obtained from six different existing assessment tools (AASHE, 2011; Lozano, 2006b; Lukman et al., 2010; Roorda, 2001; ULSF, 2001; Universitas Indonesia, 2012). Following this the indicators were classified according to the proposed sub-criteria, and reduced by elimination of duplicates and filtering based on the principles proposed by Hezri (Hezri, 2004). Starting by eliminating indicators that were too specific and giving preference was given to those covering key issues based on the robustness principle, and then eliminating indicators that were difficult to assess based on the longevity principle, in order to propose a set of indicators that could be periodically audited. Finally based on the relevance principle (Hezri, 2004), a fundamental part of the process is selecting a set of indicators that considers local priorities and data availability constrains.

To illustrate this process, the Chilean context was considered. To incorporate local priorities, a group of eight experts were asked to prioritize against every sub-criterion whose indicators would be preferable to assess the sustainability efforts in the local context. Then, the list was compared against available data, considering four Chilean HEI with sustainability reports or equivalent. As a result a final list of 25 indicators that were actually viable to calculate was obtained.

2.2.3. Using the AHP method

To calculate a final index using the proposed hierarchy it is necessary to establish the relative importance of criteria, sub-criteria and indicators. This is very difficult to

determine with sufficient accuracy (Afgan, 2004; Krajnc & Glavič, 2005), because we deal with complex phenomena, where in many cases there is no simple and objective comparison among the issues being assessed. To overcome this problem an expert consultation was conducted and processed using the analytic hierarchy process (Saaty, 1987). This method has been used to solve many complex decision making and prioritizing problems (Vaidya & Kumar, 2006), including specific applications on the field of sustainable assessment (Krajnc & Glavič, 2005; Lukman et al., 2010; Singh et al., 2007).

The AHP method decomposes the problem in a hierarchy of criteria, sub-criteria and alternatives (Lukman et al., 2010), then the various criteria at a particular level of the hierarchy are subsequently compared pair-wise in relation to the corresponding criteria in the immediate upper level by a group of experts. The comparisons are aggregated by geometric mean (Wu & Lin, 1998), and organized on a judgmental (NxN) matrix D where each element D_{ij} corresponds to aggregated pair-wise comparisons between criteria i and j. This is a positive reciprocal matrix, where the diagonal $D_{ii} = 1$ *and* $D_{ij} = (1/D_{ji})$, for $i, j = 1,\ldots,N$.
The priorities are obtained by finding and normalizing the principal eigenvector *W* of the matrix *D*, correspondent to its largest eigenvalue λ_{max}.

Once the judgmental matrix is obtained, its consistency can be estimated by a measure called the consistency ratio (C_R):

$$C_R = {C_I}/{R_I} \tag{2,1}$$

Where R_I is a random index for which Saaty (Saaty, 1987) provided values from randomly generated matrices (Table 8), and the C_I correspond to a consistency index for a matrix of order N defined as:

$$C_I = {(\lambda_{max} - N)}/{(N-1)} \tag{2,2}$$

Consistency ratios of 0.1 or less are generally considered acceptable, but for matrices of size four and three the suggested thresholds are 0.08 and 0.05 respectively. If the value exceeds this threshold the judgments might not be reliable and should be solicited again (Berrittella et al., 2007).

Size	1	2	3	4	5	6	7	8	9	10
R_I	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 8: Average consistencies of random matrices ($\mathbf{R_I}$ values)

2.2.4. Expert's consultation

The consultation processes were conducted by sending a survey with pair-wise comparison to experts. In order to facilitate the consultation, they were asked to express their preferences based on a 4 point scale to transform verbal judgments into numerical quantities, adapted from the one proposed by Saaty (Saaty, 1987).

Two consultations were made, starting by an international consultation to establish weights for criteria and sub-criteria of the proposed hierarchy, sending the survey to 112 experts obtaining 23 answers from various countries (UK, Sweden, Ireland, USA, Canada, Chile), and second a local consultation to establish the indicators weights on a local context.

Both consultation processes results showed satisfactory consistency ratios. For matrices of order 3 the maximum obtained C_R was 0.032 (<0.052), for matrices of order 4 it was 0.032 (<0.089) and for matrices of order 6 it was 0.049 (<0.1).

Once obtained, the weights for each level were aggregated in order to obtain the final weights of the indicators with respect to the goal A as follows:

$$w(I_k)_A = w(B_i)_A \sum_{ij}^{n} \left[w(I_k)_{C_j} \, w\left(C_j\right)_{B_i} \right] \qquad (2,3)$$

$w(I_k)_A$ is the weight of indicator I_k with respect to the goal A, $w(B_i)_A$ the weight of criterion B_i with respect to goal A, $w(C_j)_{B_i}$ the weight of sub-criterion C_j with respect to criterion B_i and $w(I_k)_{C_j}$ the weight of the indicator I_k with respect to sub-criterion C_j.

2.2.5. Normalization and aggregation of results

Considering that the indicators may be expressed in different units and probably include a wide range of data, to be able to aggregate them the following normalization method could be used:

$$I_{N,k}^{+} = \left(I_k - I_{min,k}\right) \Big/ \left(I_{max,k} - I_{min,k}\right) \quad (2,4)$$

$$I_{N,k}^{-} = \left(I_{max,k} - I_k\right) \Big/ \left(I_{max,k} - I_{min,k}\right) \quad (2,5)$$

Where $I_{max,k}$ and $I_{min,k}$ correspond to the maximum and minimum values obtained for the indicator k. $I_{N,k}^{+}$ is the normalized indicator k when a higher value is considered to be better and $I_{N,k}^{-}$ the opposite.

Once all data is normalized the final results are obtained by applying the following equations:

$$C_j = \sum_{jk}^{n} w(I_k)_{C_j} I_{N,k}^{+} + \sum_{jk}^{n} w(I_k)_{C_j} I_{N,k}^{-} \quad (2,6)$$

$$B_i = \sum_{ij}^{n} w(C_j)_{B_i} C_j \quad (2,7)$$

$$A = \sum_{k}^{n} w(I_k)_A \; I_{N,k}^{+} + \sum_{jk}^{n} w(I_k)_A I_{N,k}^{-} \quad (2,8)$$

Where C_j is the performance for the sub-criterion j, B_i the performance for criterion i and A the final overall rank of the HEI.

To facilitate the communication of results, the triangle method could be used to illustrate the final rank and second level results. Besides, the AMOEBA graph for the third level result, could allow a more detail comparison between HEI regarding the assessment sub-criteria.

2.3.Adaptable model for assessing sustainability in HEI (AMAS)

As a result of the application of the four step process, mentioned in 2.2, the Adaptable model for assessing sustainability in HEI (AMAS) was built.

a) Adaptation possibilities

The model can be modified in order to be used in different contexts or updated depending on the user's needs, as illustrated on Figure 8. The possible adaptations are:

- **Local adjustment:** Repeat from the third step if recalibration of weights of indicators is needed; in order to include new available data, or to expand the local consultation to more stakeholders.
- **International calibration:** Repeat from the second step in order to improve the criteria and sub-criteria weighting scheme, by extending the international consultation including more or new stakeholders.
- **Restructuring the hierarchy:** Repeat from the first step in order to consider new approaches in the sustainability assessment field that could affect the proposed theoretical framework of the model.

b) Weighted hierarchy

As a result of the full application of the four step process, a full model was obtained for application in the Chilean context. Although it could be adapted to any other

context considering results from levels two and three, which were obtained through the international consultation process.

Table 9: Criteria and sub-criteria weights

B_i Criterion	$w(B_i)_A$	C_j Sub-criterion	$w(C_j)_{B_i}$	$w(C_j)_A$
B_1 Institutional commitment	0.3614	C_1 Statement	0.1879	0.0679
		C_2 Strategies	**0.4558**	0.1647
		C_3 Coordination	0.3564	0.1288
B_2 Setting an example	**0.3816**	C_4 Diversity and equity	0.1593	0.0608
		C_5 Resource consumption	**0.5025**	0.1917
		C_6 Experience on campus	0.3382	0.1291
B_3 Encouragement for sustainability	0.2570	**C_7 Education**	**0.4677**	0.1202
		C_8 Research	0.2842	0.0730
		C_9 Public engagement	0.2481	0.0638

The resulting weighting scheme for criteria and sub-criteria, obtained from the international consultation is presented on Table 9 and the final indicator's weights, adding the local consultation, on Table 10.

According to this results the **setting an example** criterion (B2) is the most important closely followed by the institutional commitment. On the sub-criteria level, the strategy (C2), resource consumption (C5) and education (C7) sub-criteria are the most important to the corresponding criteria.

On the lower level the most important indicators are: **sustainability related programs** (I22), followed by **sustainability in the strategic institutional plan** (I4) and the **recycling program coverage** (I19), representing 32.8% of the total weight.

Table 10: Indicators weight

I_k	Indicator	C_j	$w(I_k)_{C_j}$	$w(I_k)_{B_1}$	$w(I_k)_{B_2}$	$w(I_k)_{B_3}$	$w(I_k)_A$
I_1	Sustainability sign commitments	C_1	0.1075	0.0202	-	-	0.0073
I_2	Authority's declarations related to sustainability	C_1	0.0690	0,0130	-	-	0.0047
I_3	Sustainability in the institutional vision and mission	C_1	0.3440	0.0646	-	-	0.0234
I_4	**Sustainability in the institutional strategic plan**	**C_1** **C_2**	**0.4795** **0.4934**	**0.3150**	**-**	**-**	**0.1138**
I_5	Sustainability plan	C_2	0.3421	0.1559	-	-	0.0564
I_6	Sustainability report	C_2	0.1645	0.0750	-	-	0.0271
I_7	Sustainability coordination	C_3	0.7115	0.2536	-	-	0.0916
I_8	Environmental management coordination	C_3	0.1256	0.0448	-	-	0.0162
I_9	Social responsibility coordination	C_3	0.1629	0.0581	-	-	0.0210
I_{10}	Women in high-level governance positions	C_4	0.1554	-	0.0247	-	0.0094
I_{11}	Students from low socioeconomic background	C_4	0.4803	-	0.0765	-	0.0292
I_{12}	Average career cost	C_4	0.1153	-	0.0184	-	0.0070
I_{13}	Minimum wage	C_4	0.2490	-	0.0397	-	0.0151
I_{14}	Energy consumption	C_5	0.2899	-	0.1457	-	0.0556
I_{15}	Energy efficiency measures	C_5	0.0943	-	0.0474	-	0.0181
I_{16}	Water consumption	C_5	0.2306	-	0.1159	-	0.0442
I_{17}	Water efficiency measures	C_5	0.0772	-	0.0388	-	0.0148
I_{18}	Hazardous waste management	C_5	0.1154	-	0.0580	-	0.0221
I_{19}	**Recycling program coverage**	**C_5** **C_6**	**0.1927** **0.4481**	-	**0.2484**	**-**	**0.0948**
I_{20}	Sustainability web site	C_6	0.1331	-	0.0450	-	0.0172
I_{21}	Sustainability outreach campaigns	C_6	0.4188	-	0.1417	-	0.0541
I_{22}	**Sustainability related programs**	**C_7**	**1.0000**	**-**	**-**	**0.4677**	**0.1202**
I_{23}	Sustainability related research	C_8	1.0000	-	-	0.2842	0.0730
I_{24}	Sustainability related presence on the web	C_9	0.6500	-	-	0.1613	0.0414
I_{25}	Inter-Campus Collaboration on Sustainability	C_9	0.3400	-	-	0.0844	0.0217

c) Indicators rationale

In order to calculate the indicators, it is important to consider that they might be based on quantitative and qualitative data. So in order to adequately process this information the following process is proposed.

For qualitative information, the user can grade each indicator by applying a verbal rating scale such as the one proposed by Lozano with five different choices, 0 – 4, where:

0. There is a total lack of information for the indicator, it is non-existent.
1. The information presented is of poor performance.
2. The information presented is of regular performance.
3. The information presented is considered to be of good performance.

4. The information has an excellent performance.

It should be noted that the performance is dependent on the indicator being assessed, so the verbal rating should always be understood separately under each situation.

For quantitative information, there are three kinds of indicators: binary, total amount, and performance. The binary indicators have only two possible outcomes; meet or do not meet the criteria, assigning it 1 or 0 respectively. Total amount indicators; correspond to those where the raw data is sufficient for comparison. Finally performance indicators require information to be compared against the relative size or impact of the HEI, to avoid as much as possible contextual distortions. For this, it is necessary to gather general information to build a base line of the HEI, such as:

- People: number of students, number of workers (ideally as equivalent full-time person load), total amount of people in high level governance committees.
- Area: Total gross floor area.
- Curricular: Total number of programs and courses.
- Web: Total presence on the web of the HEI.
- Research: Total number of research papers.

Considering the previous recommendations, the indicators obtained for the Chilean application are separated between qualitative and quantitative, and explained.

Qualitative indicators:

- I_3. Sustainability in the institutional vision and mission.
- I_4. Presence of sustainability in the institutional strategic plan.
- I_5. Sustainability report: Does it counts with a sustainability report? Does it cover all important issues?
- I_{15}. Energy efficiency measures: What efforts are being made to reduce energy consumption?

- I_{17}. Water efficiency measures: What efforts are being made to reduce water consumption?
- I_{18}. Hazardous waste management: What efforts are being made to minimize and safely dispose of all hazardous waste?
- I_{19}. Recycling program coverage: What efforts are being made to reduce waste and conserving resources by recycling and composting?
- I_{20}. Sustainability web site: Does it have a complete and dynamic sustainability web site?
- I_{21}. Sustainability outreach campaigns: What efforts are being made to spread and promote the sustainability principles within the institution community through outreach campaigns?
- I_{25}. Inter-Campus Collaboration on Sustainability: What efforts are being made to collaborate with other HEI on sustainability issues?

Quantitative indicators:

- I_1. Sustainability sign commitments: Total number of commitments signed by the HEI.
- I_2. Declarations by authorities related to sustainability: Number of public declarations by the highest authority related to sustainability efforts being made by the HEI.
- I_5. Sustainability plan: Does it count with a sustainability plan? (Binary yes/no).
- I_7. Sustainability coordination: Does it count with some kind of sustainability coordination? (Binary yes/no).
- I_8. Environmental management coordination: Does it count with some kind of environmental management coordination? (Binary yes/no).
- I_9. Social responsibility coordination: Does it have some kind of social responsibility coordination? (Binary yes/no).

- I_{10}. Proportion of women in high level governance committees: Women in high-level governance committees / total amount of people in high level governance committees.
- I_{11}. Students from low socioeconomic background: Students from fully and partially public funded schools/ total students.
- I_{12}. Average career cost: Average tuition for one year for all programs offered by the institution.
- I_{13}. Minimum wage: Paid by the institution.
- I_{14}. Energy: Total direct energy consumption (Electric, gas, diesel) / gross floor area
- I_{16}. Water consumption: Total direct water consumption / (total students plus equivalent full-time person time load)
- I_{22}. Sustainability related programs: Total sustainability related programs / total programs.
- I_{23}. Sustainability related research: Total sustainability related research / total research
- I_{24}. Sustainability related presence on the web: Total sustainability related web presence of the HEI / total web presence of the institution.

2.4.Discussions and conclusion

The internalization of sustainability in a HEI can be facilitated by the use of sustainability assessment tools, by benchmarking against others institutions or to a vision of sustainability success. Although the tools proposed to date deliver valuable contributions in this regard, they are not appropriate to assess sustainability efforts in HEI within different context and data availability scenarios.

The tools reviewed in this paper showed some new approaches in this matter, with proposals that do not necessarily compete with each other, delivering solutions for different needs or scale of applications. For international ranking, the TUR model

has more potential than the rest, given the relative simplicity of the proposed indicators. For national benchmarking the STARS tool could be used if we are dealing with a context of advanced sustainability efforts, and appropriate as a route map toward sustainability for beginners. The GASU tool is useful as a complement for a sustainability report based on the GRI guidelines.

Graphical support can play a significant role in the assessment process, and both TUR and GASU tools cover this subject with useful proposals.

The analytical hierarchy process (AHP) method proved to be useful and relatively simple to implement, in order to establish weights for criteria, sub-criteria and indicators. It allows for continual improvements by expanding the consultation to more or new groups of experts. The aggregation of weights is simple and allows for one indicator to be associated to different sub-criteria, which is useful considering that the sustainability effort require for incremental integration of functions in HEI system.

The four step process (Figure 8), provides a proposal for the creation and improvement of assessment models. This paper covered the application of the three first steps of the process in order to create the AMAS tool, which includes; a four level assessment hierarchy with the corresponding criteria, sub-criteria and indicators (Figure 9); a complete set of weights for the criteria and sub-criteria level (Table 9), applicable in any context; and a complete set of indicators with their respective weights (Table 10), applicable to the Chilean context.

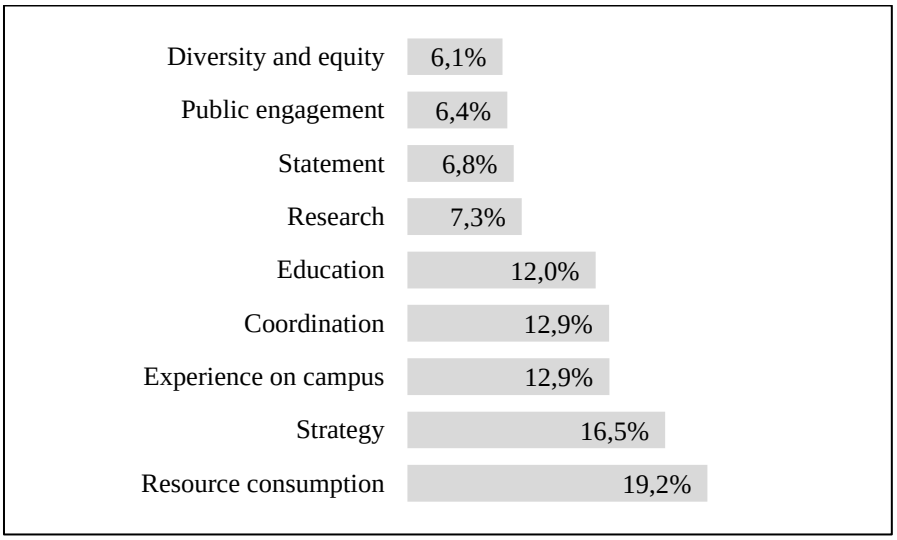

Figure 10: Predominance of sub-criterions

The obtained weights from the international consultation process showed a preference for de institutional commitment and setting an example criterion, with 36.1% and 38.2% weights respectively, and less preference for the encouragement for sustainability criterion with a 25.7% weight. On the sub-criteria level (Figure 10), the resource consumption themes were indicated as more important, similar to other assessment tools, but when compared to other sub-criteria it can be seen that the strategy, experience on campus, coordination and education were also highly rated by experts.

Future research will consider a full application of the four step process to the Chilean context, in order to establish the first comparative sustainability assessment for HEI being made in this country and also allowing to evaluate the applicability and possible improvements of the AMAS model.

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APPENDICES

APPENDIX A. CALCULATION DETAILS

In order to illustrate the process followed to obtain the hierarchy weights, examples or detailed calculation procedures are presented for each step of the process.

1. From individual pairwise comparison to the judgmental matrix

Each question presented the Appendix B, correspond to a pairwise comparison between two criterions or sub-criterions, with respect to an element from the higher level.
As an example we can see the following questions:

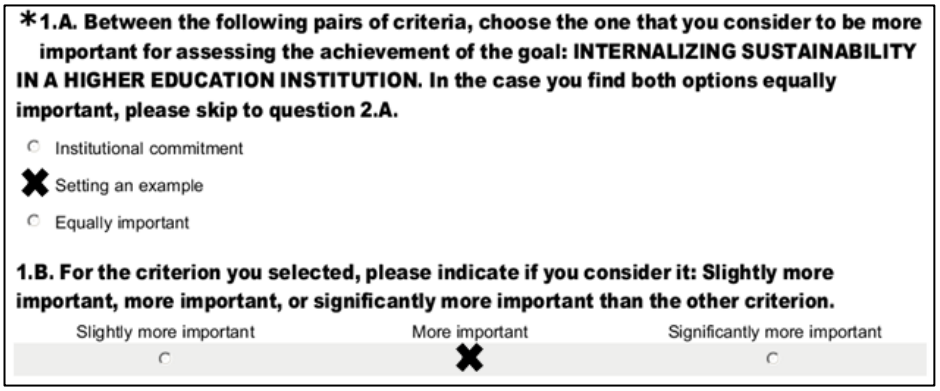


Figure 11: Example of pairwise comparison question

These questions correspond to a pairwise comparison between the Institutional commitment (IC) criterion and the setting an example (SE) criterion. The answer presented on the example is verbally understood as the SE criterion is more important than the IC criterion when trying to achieve the goal “Internalizing sustainability in a HEI”, and its numerical representation on a judgmental matrix is:

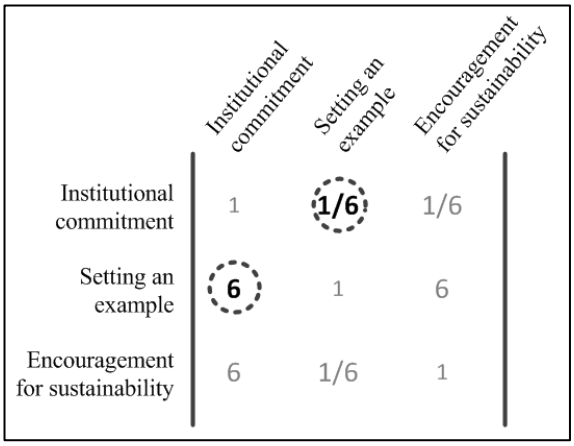


Figure 12: Example of a judgmental matrix

Where the marked number 6 represents that the SE criterion is six times more important than the IC criterion for assessing the achievement of internalizing sustainability in a higher education institution, and the marked 1/6 its reciprocal number.

2. Aggregation of individual judgmental matrices

Defining the judgmental matrices D^k, where k = 1,2,3,…m, represents individual experts. And each element d_{ij}^k represents the pairwise comparison made by the expert k between element i and j (e.g. criterions i and j).

$$\mathrm{D}^k = \begin{bmatrix} 1 & d_{12}^k & \cdots & d_{1n}^k \\ 1/d_{12}^k & 1 & \dots & d_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ 1/d_{1n}^k & 1/d_{2n}^k & \dots & 1 \end{bmatrix} \qquad \text{(A,1)}$$

The aggregated judgmental matrix D is obtained using the geometric mean as follows:

$$\mathrm{D} = \begin{bmatrix} 1 & \sqrt[m]{\prod_{k=1}^{m} d_{12}^k} & \cdots & \sqrt[m]{\prod_{k=1}^{m} d_{1n}^k} \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} d_{12}^k}} & 1 & \dots & \sqrt[m]{\prod_{k=1}^{m} d_{2n}^k} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} d_{1n}^k}} & \frac{1}{\sqrt[m]{\prod_{k=1}^{m} d_{2n}^k}} & \dots & 1 \end{bmatrix} \qquad \text{(A,2)}$$

3. Obtaining the maximum eigenvalue of the judgmental matrix

The priorities are obtained by finding and normalizing the principal eigenvector W of the matrix D, correspondent to its largest eigenvalue λ_{max}.

The principal eigenvalue is obtained by numerical calculations using an excel spreadsheet to solve the following equation:

$$W(D - \lambda_{max}\, I) = 0$$
(A,3)

Where $W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ w_n \end{bmatrix}$, is the raw vector of priorities of the judgmental matrix D, and I correspond to an a identity matrix of order n.

In order to estimate the maximal eigenvalue, the goal seek tool was used, setting the determinant of the $(D - \lambda_{max}\, I)$ matrix to minimum by iterating on the λ_{max} value.

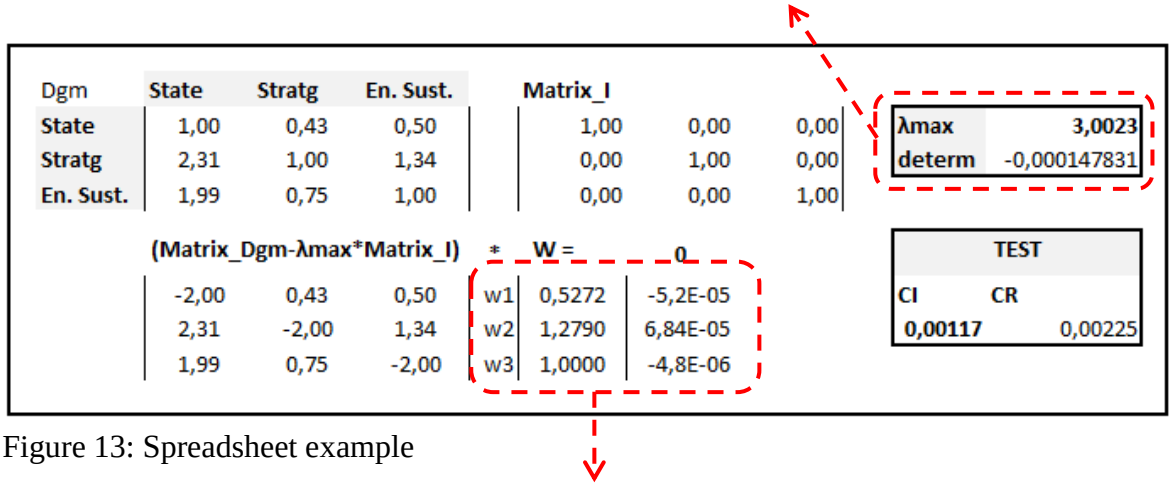


Figure 13: Spreadsheet example

The eigenvector was estimated using the solver tool, setting the result of the $W(D - \lambda_{max}\, I)$ matrix to the minimum iterating the W vector values.

The example in Figure 13 shows the spreadsheet used for the calculation of the eigenvector of the sub-criterions related to the institutional commitment criterion. Where the resulting eigenvector is:

4. Normalizing priorities

In order to obtain the weights, the eigenvector needs to be normalized as follows:

$$\bar{W} = \begin{bmatrix} w_1 / \sum_{k=1}^{k=n} w_k \\ w_2 / \sum_{k=1}^{k=n} w_k \\ \vdots \\ w_n / \sum_{k=1}^{k=n} w_k \end{bmatrix} \qquad \text{(A,4)}$$

APPENDIX B. INTERNATIONAL SURVEY

Internalizing Sustainability in a Higher Education Institution

Introduction

(To skip the introduction click "Next" at the bottom of the page)

Dear participant

Framed in multiple global efforts to implement sustainability in higher education institutions, there have been important developments in tools that measure qualitatively and quantitatively the degree of success of these projects.

As researchers from the Engineering School of the Catholic University of Chile, supported by the Sustainability Office of the same institution, we are developing a study of the relative importance of different assessing criteria for sustainability projects, in order to contribute to this discussion and improve these Tools.

Part of this research project require an international consultation to those professionals who have been involved in sustainability projects in higher education throughout their line of work. It is for this reason that we ask for your support in responding to this brief survey, methodologically based on a pairwise comparison (Saaty, 1980).

- The survey consists of 20 questions that can be answered in about 10-12 minutes.
- Participation is voluntary.
- The results will be reported as an aggregate, without identifying participants.
- The information collected will be kept confidential in a secure server and only the main researcher will be able to access such information.
- Individual responses will not be shared with people outside the research team.
- Those who complete the survey will receive a confidential summary of the results upon written request to the email address specified below.
- Any questions regarding the survey may be sent to Francisco Urquiza, fjurquiz@uc.cl

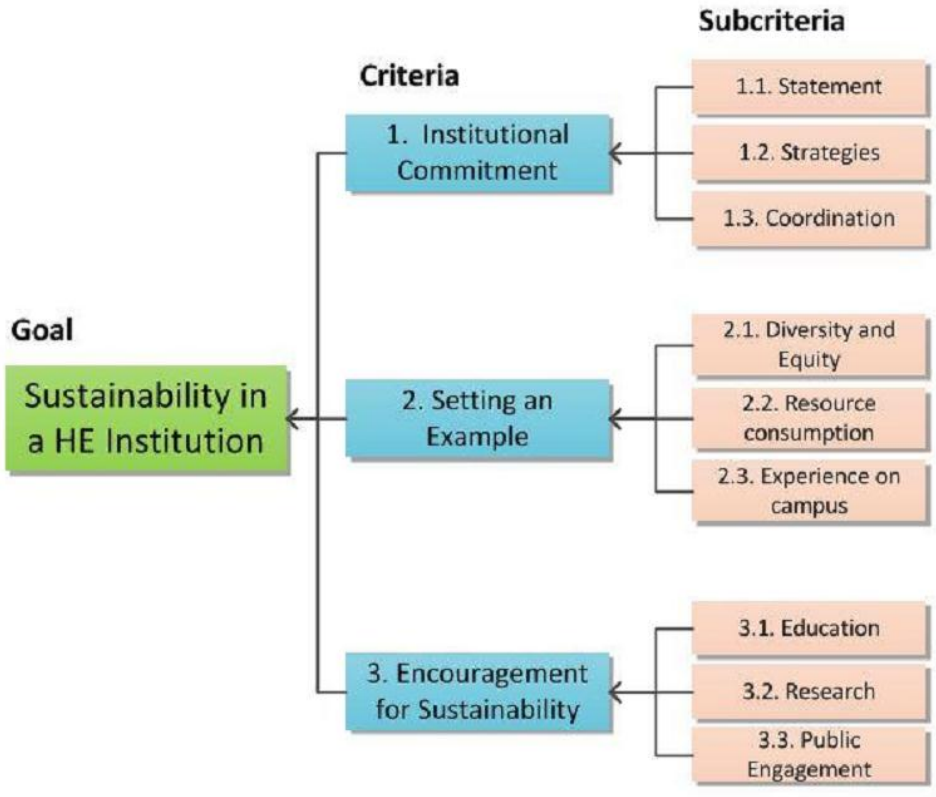
Internalizing Sustainability in a Higher Education Institution

Instructions

Questions in the survey are divided as follows:

- A: Identify the importance of criteria 1, 2, and 3 for assessing the achievement of the GOAL: Internalizing sustainability in a Higher Education Institution
- B: Identify the importance of the subcriteria 1.1, 1.2, and 1.3 to evaluate CRITERION 1: Institutional Commitment.
- C: Identify the importance of the subcriteria 2.1, 2.2, and 2.3 to evaluate CRITERION 2: Setting an Example.
- D: Identify the importance of the subcriteria 3.1, 3.2, and 3.3 to evaluate CRITERION 3: Encouragement for Sustaninability.

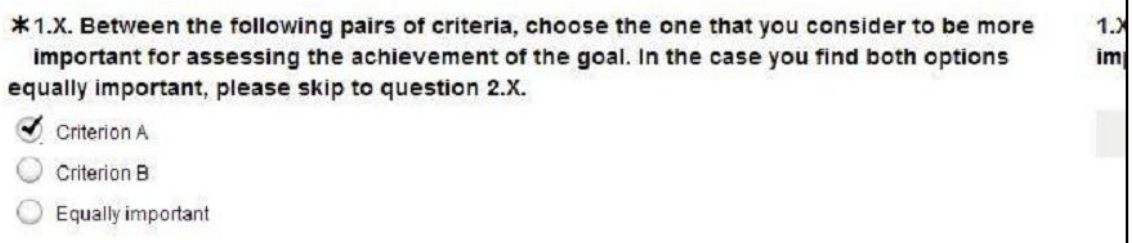
Hierarchy used in the evaluation



Internalizing Sustainability in a Higher Education Institution

Questions are based on a pairwise comparison. For each OBJECTIVE being evaluated, two criteria will be presented, you must choose the one that think is more important in evaluating the achievement of the objective. Once you have chosen a criterion you will be asked to indicate how much more important you believe the chosen criterion is compared to the alternative option.

Example:



In this case the response indicates that the criterion A would be Significantly more important than the criterion B.

Internalizing Sustainability in a Higher Education Institution

A. GLOBAL OBJECTIVE: SUSTAINABILITY IN A HIGHER EDUCATION INSTITUTION

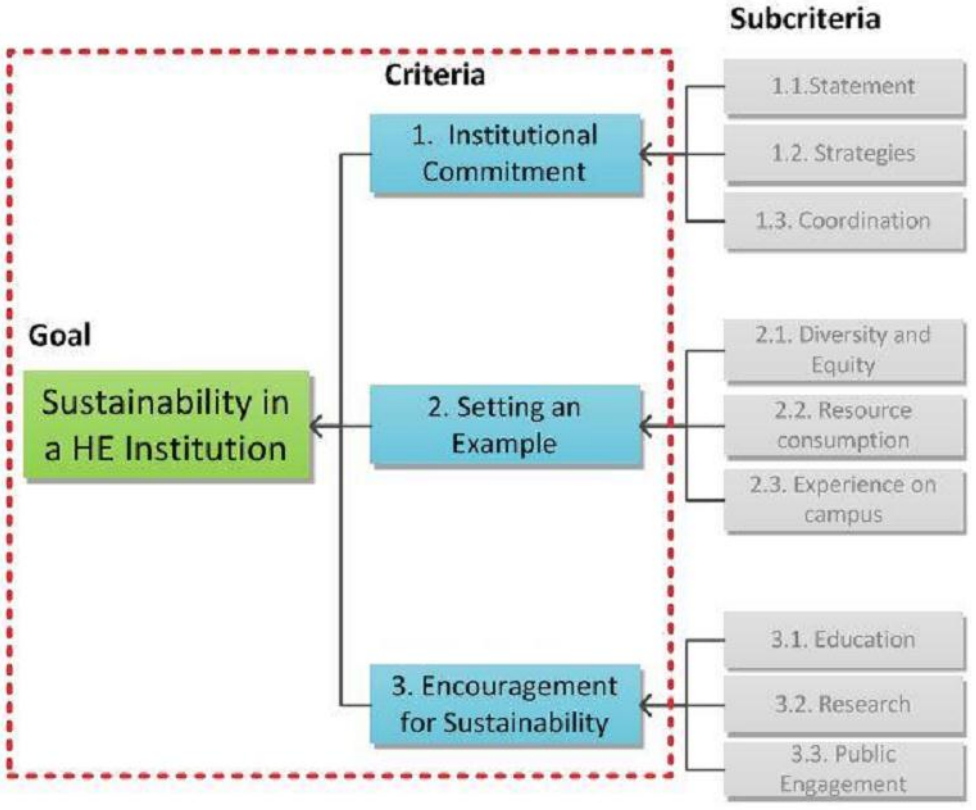
Based on an extensive literature review, we propose three criteria for assessing the achievement of the goal: INTERNALIZING SUSTAINABILITY IN A HIGHER EDUCATION INSTITUTION:

CRITERIA:

1-INSTITUTIONAL COMMITMENT: To count with an effective institutional commitment for long-term sustainability.
Examples: Written statements, incorporation in strategic planning, assembly of a sustainability coordination (committee, office or equivalent).

2-SETTING AN EXAMPLE: Setting an example for social and environmental responsibility.
Examples: Fair wages, representation of social minorities, responsible resource consumption, energy efficiency, recycling system, encouraging leadership.

3-ENCOURAGEMENT FOR SUSTAINABILITY: Institution's contribution to sustainable development through professional training, research, and extension programs.
Examples: Courses specialized in or related to sustainability, research, community service, academic centers or institutes, seminars, conferences.



Internalizing Sustainability in a Higher Education Institution

***1.A. Between the following pairs of criteria, choose the one that you consider to be more important for assessing the achievement of the goal: INTERNALIZING SUSTAINABILITY IN A HIGHER EDUCATION INSTITUTION. In the case you find both options equally important, please skip to question 2.A.**

- ○ Institutional commitment
- ○ Setting an example
- ○ Equally important

1.B. For the criterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other criterion.

Slightly more important	More important	Significantly more important
○	○	○

***2.A. Between the following pairs of criteria, choose the one that you consider to be more important for assessing the achievement of the goal: INTERNALIZING SUSTAINABILITY IN A HIGHER EDUCATION INSTITUTION. In the case you find both options equally important, please skip to question 3.A.**

- ○ Institutional commitment
- ○ Encouragement for sustainability
- ○ Equally important

2.B. For the criterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other criterion.

Slightly more important	More important	Significantly more important
○	○	○

***3.A. Between the following pairs of criteria, choose the one that you consider to be more important for assessing the achievement of the goal: INTERNALIZING SUSTAINABILITY IN A HIGHER EDUCATION INSTITUTION In the case you find both options equally important, please skip to question 4.**

- ○ Setting an example
- ○ Encouragement for Sustainability
- ○ Equally important

3.B. For the criterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other criterion.

Slightly more important	More important	Significantly more important
○	○	○

Internalizing Sustainability in a Higher Education Institution

B. CRITERIA 1: INSTITUTIONAL COMMITMENT

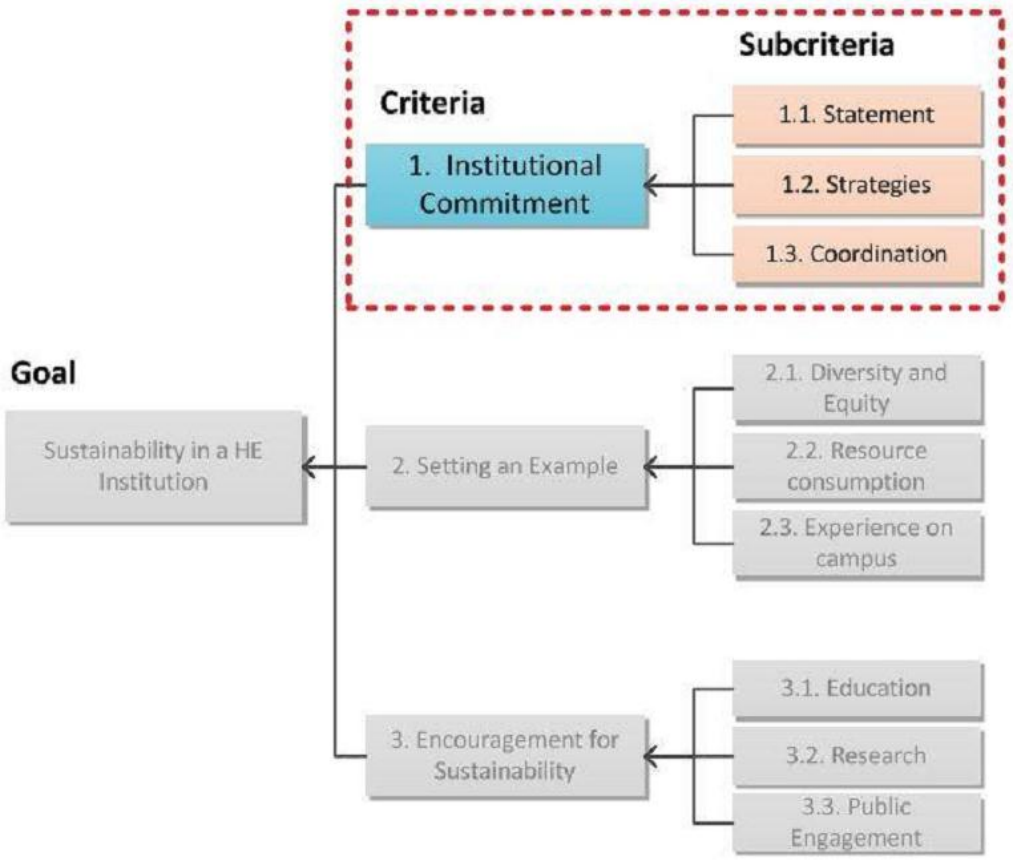
The following sub-criteria have been proposed to assess the 'INSTITUTIONAL COMMITMENT' criterion, that is to say, the commitment to long term sustainability formalized through written statements, the incorporation of sustainability in strategic planning and the assignment of responsibilities within the institution.

SUB-CRITERIA:

1.1-STATEMENT: Role and commitment to sustainable development in formal institutional documentation.
Examples: Written and signed statements, presence of sustainability in the mission and/or vision of the institution, signed declarations (Talloires, Barcelona, others).

1.2-STRATEGY: Commitment to sustainable development in institutional planning and evaluation.
Examples: Institution's strategic plan, development plan, tools for internal evaluation.

1.3-COORDINATION: Existence of an entity specialized in coordinating and promoting the efforts regarding sustainability within the institution.
Examples: Committees, office, coordinators, programs, others.



Internalizing Sustainability in a Higher Education Institution

***5.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'INSTITUTIONAL COMMITMENT' criterion. In the case you find both options equally important, please skip to question 6.A.**

- ○ Statement
- ○ Strategies
- ○ Equally important

5.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

***6.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'INSTITUTIONAL COMMITMENT' criterion. In the case you find both options equally important, please skip to question 7.A.**

- ○ Statement
- ○ Coordination
- ○ Equally important

6.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

***7.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'INSTITUTIONAL COMMITMENT' criterion. In the case you find both options equally important, please skip to question 8.**

- ○ Strategy
- ○ Coordination
- ○ Equally important

7.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

8. Would you propose other subcriteria that allow for better evaluation of the 'INSTITUTIONAL COMMITMENT' criterion?

Internalizing Sustainability in a Higher Education Institution

C. CRITERIA 2: SETTING AN EXAMPLE

The following sub-criteria have been proposed to assess the 'SETTING AN EXAMPLE' criterion, that is to say, the institutional example of social and environmental responsibility practices, such as fair wages, representation of social minorities, responsible resource consumption, training campaigns, energy efficiency, recycling system.

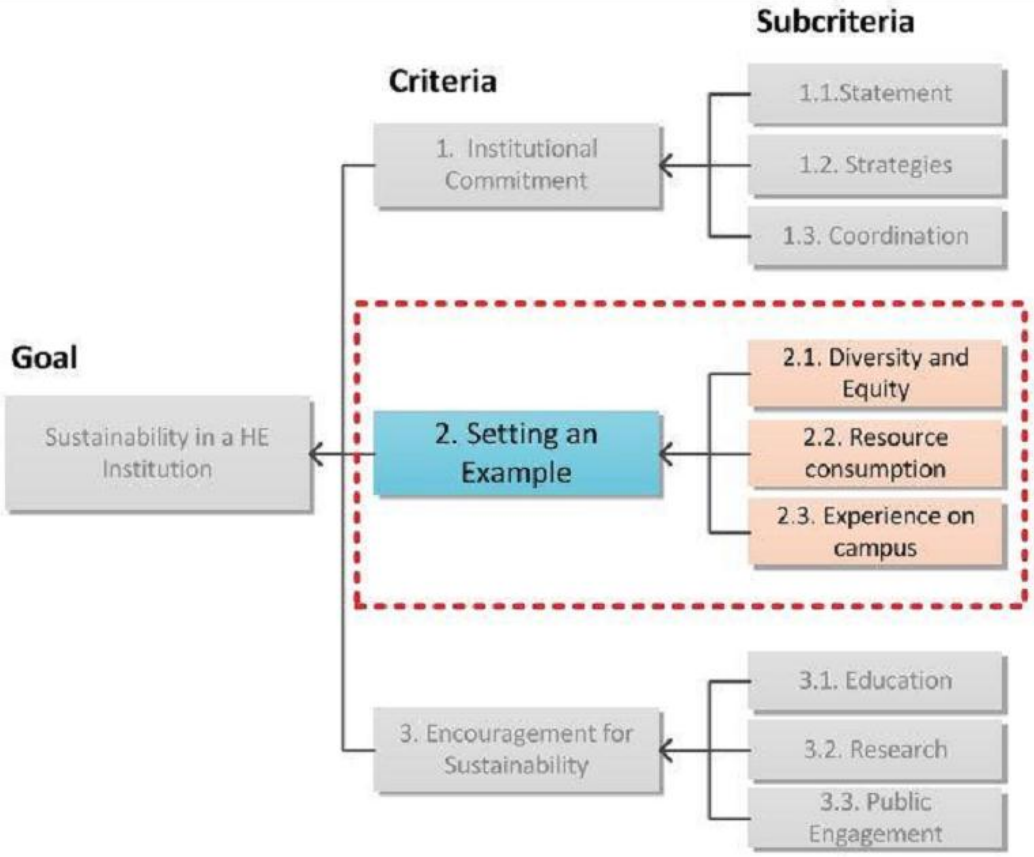
SUB-CRITERIA:

2.1-DIVERSITY AND EQUITY: Encourage equal opportunities as an inclusive and diverse institution that rejects any type of discrimination, being it in terms of gender, sexual orientation or socioeconomic status.
Examples: Fair wages, balanced representation and pay for both men and women, and representation and benefits for social minority groups.

2.2-RESOURCE CONSUMPTION: Reduce and, as far as possible, eliminate the social and environmental impacts associated with resource consumption on the institution.
Examples: Energy efficiency, responsible purchasing, recycling system, efficiency measures in water consumption, encouraging the use of less polluting transportation.

2.3-EXPERIENCE ON CAMPUS: The constant presence of sustainability in the experience of campus life. May this be through its internal communications, community training programs, student participation.
Examples: Dissemination campaigns, existence of student groups, and training for sustainability leadership.

Internalizing Sustainability in a Higher Education Institution



***9.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'SETTING AN EXAMPLE' criterion. In the case you find both options equally important, please skip to question 10.A.**

- ○ Diversity and equity
- ○ Resource consumption
- ○ Equally important

9.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

Internalizing Sustainability in a Higher Education Institution

***10.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'SETTING AN EXAMPLE' criterion. In the case you find both options equally important, please skip to question 11.A.**

- ○ Diversity and equity
- ○ Experience on campus
- ○ Equally important

10.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

***11.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'SETTING AN EXAMPLE' criterion. In the case you find both options equally important, please skip to question 12.**

- ○ Resource consumption
- ○ Experience on campus
- ○ Equally important

11.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

12. Would you propose other subcriteria that allow for better evaluation of the 'SETTING AN EXAMPLE' criterion?

Internalizing Sustainability in a Higher Education Institution

D. CRITERIA 3: ENCOURAGEMENT FOR SUSTAINABILITY

The following sub-criteria have been proposed to evaluate the 'ENCOURAGEMENT FOR SUSTAINABILITY' criterion, that is to say, institutional contribution to sustainable development beyond the campus (as opposed to societal) through the training of professionals, research, and external community-oriented projects.

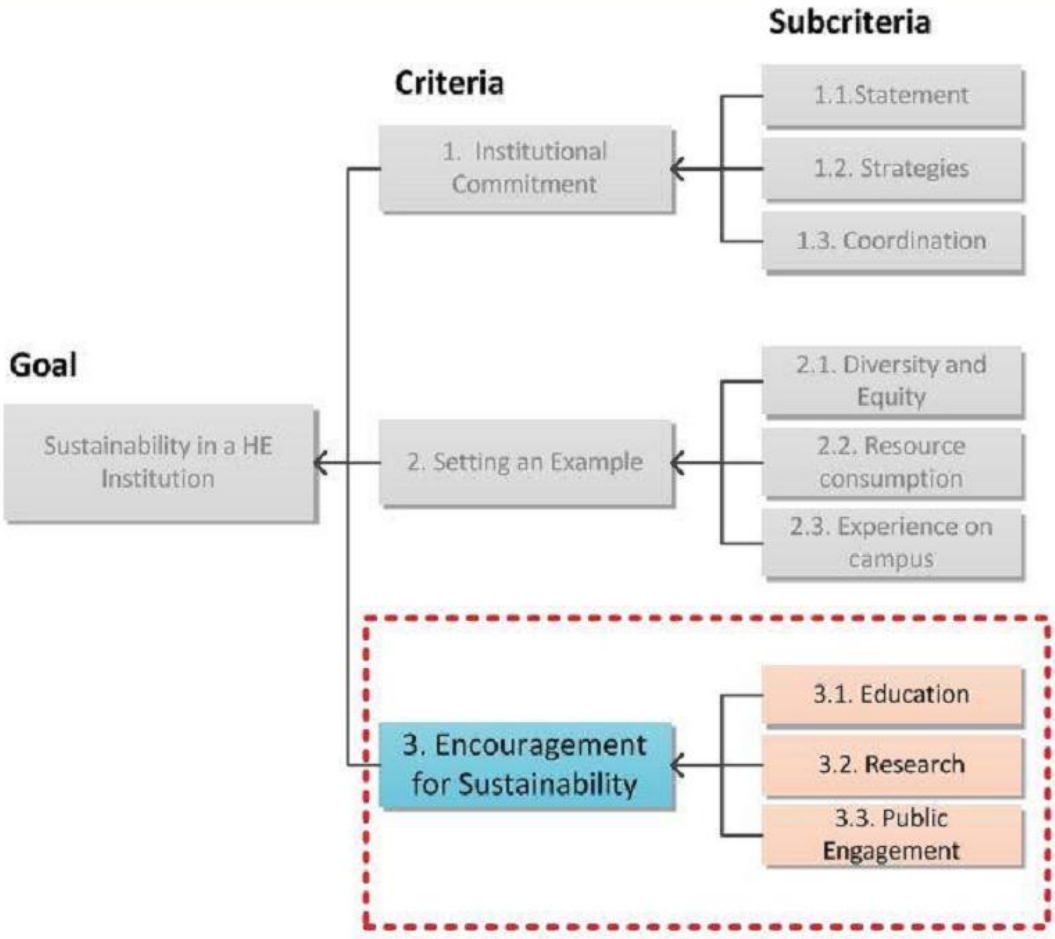
SUBCRITERIA:

3.1-EDUCATION: Development of professionals with the necessary skills to contribute to the construction of a more responsible, equitable and environmentally concerned society.
Examples: Courses specialized or related to sustainability, specialized training programs.

3.2-RESEARCH: The promotion of research that contributes to the general comprehension of difficulties regarding sustainable development, as well as of new technologies, strategies and approaches that enable people to confront these problems and create new opportunities.
Examples: Specialized or related Sustainable Development research, encouraging interdisciplinarity.

3.3-PUBLIC ENGAGEMENT: Connection between institutional activities and the challenges 'beyon campus' concerning sustainable development.
Examples: Community service, centers or institutes dedicated to the dissemination and promotion of sustainable development in communities, seminars, conferences.

Internalizing Sustainability in a Higher Education Institution



***13.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'ENCOURAGEMENT OF SUSTAINABILITY' criterion. In the case you find both options equally important, please skip to question 14.A.**

- ○ Education
- ○ Research
- ○ Equally important

13.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

Internalizing Sustainability in a Higher Education Institution

***14.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'ENCOURAGEMENT OF SUSTAINABILITY' criterion. In the case you find both options equally important, please skip to question 15.A.**

- ○ Education
- ○ Public engagement
- ○ Equally important

14.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

***15.A. Between the following pairs of subcriteria, choose the one that you consider to be more important for assessing the 'ENCOURAGEMENT OF SUSTAINABILITY' criterion. In the case you find both options equally important, please skip to question 16.**

- ○ Research
- ○ Public engagement
- ○ Equally important

15.B. For the subcriterion you selected, please indicate if you consider it: Slightly more important, more important, or significantly more important than the other subcriterion.

Slightly more important	More important	Significantly more important
○	○	○

4. Are you aware of the existence of other criteria that allow for better evaluation of the 'ENCOURAGEMENT OF SUSTAINABILITY' criterion?