Environmental Engineering and Management Journal

June 2020, Vol.19, No. 6, 985-996
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

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INSTRUMENT FOR ASSESSING THE SUSTAINABLE INNOVATION CAPACITY OF PROFESSIONALS IN CONSTRUCTION

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Abstract

Architects and engineers play an important role in the choice of innovative and environmentally sustainable materials and techniques. To define these materials and techniques, they mobilize competencies acquired throughout their lives. To learn the profile of the environmentally innovative architect and engineer in Brazil, we created a self-assessment instrument that allows us to identify essential characteristics in practice, namely, which competencies are mobilized when they choose an environmentally innovative material and/or technique. Our study uses the concept of competencies, which proposes an analysis of four dimensions: Professional, organizational, innovative and customer-related. The instrument consists of a validated scale of 64 items of professional profile evaluation, which was applied to 95 selected professionals. The items were elaborated based on a literature review and on the authors' personal experiences. We used the IRT (item response theory) model for psychometric analysis; our properties of interest were dimensionality, reliability, validity, and scalability. Because this instrument is divided into sections, it can be analyzed by blocks or as a single scale. It is ready to use, and its internal consistency ranges from acceptable to excellent, with varying degrees of difficulty for the latent traits.

Keywords: architects, competencies, engineers, environmental innovation

Received: June, 2019; Revised final: December, 2019; Accepted: January, 2020; Published in final edited form: June, 2020

1. Introduction

This article proposes an Instrument for Assessing the Capacity for Sustainable Innovation (IACIS) of architects and engineers through the construction and psychometric validation of a scale of professional competencies. IACIS consists of a psychological assessment questionnaire capable of measuring, evaluating, and describing behaviors and attitudes through a scale. A scale is a form of psychometric measurement to measure observable items that express a psychological construct. IACIS met the requirements described in the theoretical, empirical, and analytical poles according to the methodology of Pasquali (2011) for construction, validation, precision, and standardization of scales. IACIS was inspired by the model of self-assessment of competencies proposed by Zarifian (2003). It allows employers and employees to identify competencies considered essential for innovation in environmental sustainability among the competencies mobilized.

2. Material and methods

2.1. Scale construction and validation

The instrument was constructed by dividing it into three major poles: theoretical, empirical and analytical.

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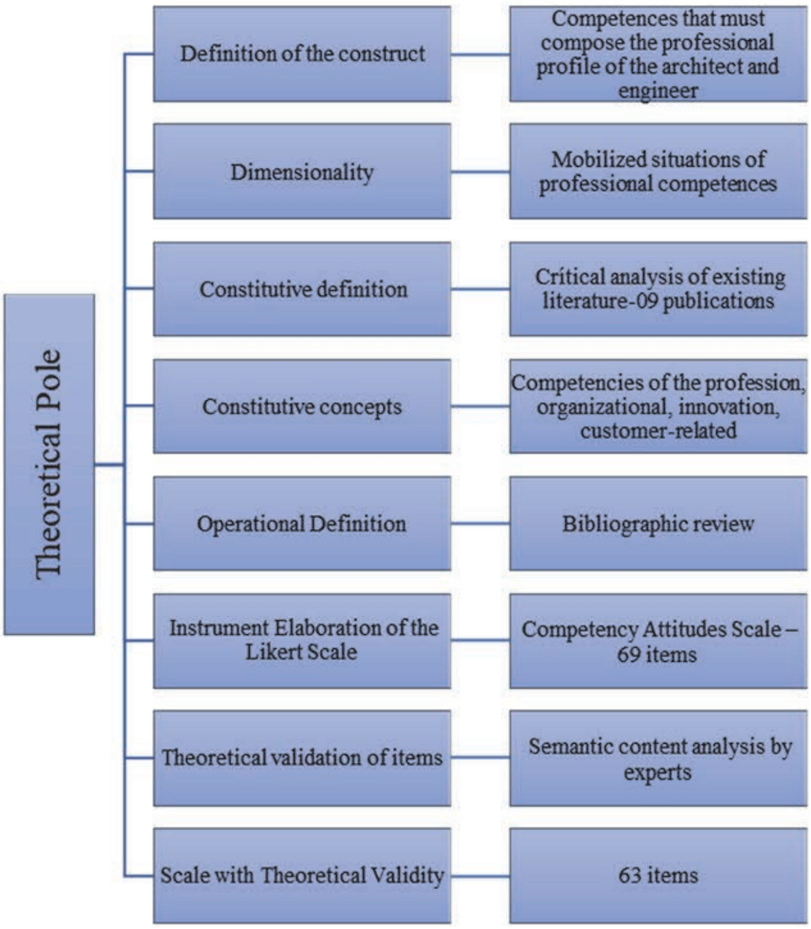
2.2. Theoretical Pole: instrument creation and pre-test

The theoretical pole is the stage in which we focus on the theory that will determine the psychological object for which one wants to construct a measuring instrument (Pasquali, 1996; Pasquali, 2011). Our psychological object of interest is the competencies that should be part of the professional profile of the environmentally innovative architect and engineer. We used the concept of competencies described by Zarifian (2003), with four specific dimensions: professional, organizational, innovative, and customer-related. These are the constituent attributes of attitudes.

The dimensionality of the construct corresponds to the internal structure and semantics of the attribute, and this attribute is the factor that makes up the construct. Scales are defined as *one-dimensional* when they use numbers to express only one dimension, and *multidimensional* when they measure several latent, independent traits. Although IACIS has four different dimensions, they all evaluate the same trait: the environmental innovation capacity of architects and engineers; therefore, it is considered one-dimensional. After the constitutive definition to define the dimensions and attributes of the constructs, the preliminary concepts of our study were submitted to an integrative review. Based on the operational concepts, we moved on to the elaboration of the preliminary version of IACIS. Here, built a list of behavioral categories, called items.

We built 69 items according to the constitutive and operational definitions of the attitudes of architects and engineers considering the bibliographic review and the organization and chaining of sentences. We chose the five-point Likert psychometric scale, which ranges from extremely important to unimportant, to build our research instrument. Its preliminary version was submitted to a pre-test conducted by 09 specialists based on their background: 03 architects and 03 engineers specialized in environment and technological innovation, a PhD in nursing specialized in social relations, a teacher of Brazilian Portuguese, and a psychologist.

All specialists were asked to make suggestions in order to improve consistency, understanding (semantic analysis) and level of difficulty. According to the answers we obtained, the instrument was reduced to 63 competencies: 13 professional, 20 organizational, 24 innovative, and 6 relational, customer-oriented (Table 2). The instrument was now ready for empirical tests.



[IMAGE: POLE CAN = THEORETICAL POLE]

Fig. 1. The sequence of specific steps and methods used to develop IACIS

The professional profile questions consisted of a 5-point Likert scale and two dichotomous questions (*Do you Know it?* and *Have you ever done it?*). All questions were close-ended.

2.3. Empirical Pole: the field search

IACIS used the intentional non-probabilistic snowball sampling. Our inclusion criteria were: college degree in architecture, engineering or related areas that qualify professionals to work on construction projects; work in construction or in related academic fields; and work with environmental sustainability at any level. Subjects who did not meet any of the inclusion criteria were excluded from our sample. The data collection instrument was elaborated on the Google Forms platform and made available for response online between November 12, 2015 and January 05, 2016 at http://goo.gl/forms/NqLO8dZ16f. Table 1 shows the profile of our respondents.

2.4. Analytical Pole: instrument validation

The analytical pole determines the final selection of items and the evaluation of the psychometric parameters of the instrument. In this stage, statistical tests were performed for validation, precision, and standardization. Our Results and Discussion sections include more details on the analytical pole.

3. Results and discussion

In the statistical analysis, dimensionality was analyzed using the *nFactors* package available for R, and the analysis using the item response theory (IRT) was performed utilizing the Winsteps software.

IACIS proposes four dimensions, represented by the competency groups A, B, C, and D. Each of these dimensions can be understood as an individual scale; however, they may also be considered simultaneously, as a single scale. To verify if the instrument met all the properties described previously, dimensions A, B, C and D were first evaluated separately, and later as a unified measure.

To analyze psychometric properties, we considered reliability, dimensionality, validity and scalability.To analyze dimensionality, the combination of parallel analysis was used. Factors were retained when the eigenvalues of the observed database were higher than at a random basis

3.1. Dimensionality

According to parallel analysis, optimized coordinates, and acceleration factor, at least one factor was retained in dimensions A, B, and C as individual scales. The dimensionality of the unified scale indicates that, when consolidated into a single measure, scales A, B, C and D produce a one-dimensional measure (Fig. 2)

3.2. Reliability

In our cross-sectional study, we evaluated three types of reliability coefficients: Cronbach's alpha, person reliability, and item reliability. The Spearman-Brown model was used for person and item reliability, and calculated in Winsteps Software as:

Predicted reliability = RT = T * RC / (C * (1-RC) + T * RC)

.

Table 1. Characterization of participants

Characteristic	***Characteristics Frequency (%)***			
Sex	Male 53 %	Female 47 %		
Institution	Public 38 %	Private 62 %		
Education	Architecture 53 %	Engineering 39 %	Other 8 %	
Other training	No 62 %	Yes 38 %		
Completion time	Up to 2 years 12 %	From 2 years to 5 years 26 %	From 5 years to 10 years 26 %	*More than 10 years* 36 %
Level of education	*Graduation* 32 %	Post-Graduation 24 %	Master Degree 28 %	PhD 16 %
Works in educational training	**No** 14 %	*Yes* 86 %		
Origin (Brazilian Major Region)	South 3 %	Southeast 87 %	North 2 %	Northeast 7 %
	Midwest 1%			
Occupation	Specialist 42 %	Manager 44 %	Education 14 %	
Main role	Specialist 18 %	Manager 51 %	Education 31 %	

Table 2. IACIS version after pre-test

Item	*Professional competencies*	*Do you know it?*		*Have you ever done it?*		*Level of importance for professional development*				
		Y	N	Y	N	5	4	3	2	1
A	**Competencies of the profession**									
1	Work with structured design in stages, from the feasibility study to the executive project									
2	Check bioclimatic conditions of the area before designing the project									
3	Use the atlas and solar plants to define free spans, energy, lighting and ventilation systems									
4	Participate in construction waste management planning									
5	Check water resources in the development area									
6	Use techniques to reduce production waste materials and workflow (lean construction)									
7	Use techniques to reduce the consumption of materials and encourage their qualified use (clean construction)									
8	Use the Brazilian bioclimatic zoning to define building materials for sealing									
9	Discard construction/demolition residues properly									
10	Use rainwater retention techniques for later use									
11	Propose the use of the construction and demolition waste management plan									
12	Choose materials disregarding environmental certification									
13	Choose materials with low maintenance cost in the short term									
B	**Organizational Competencies**									
1	Participate in quality and productivity programs									
2	Select materials and suppliers based on product quality									
3	Select materials and vendors based on product cost									
4	Check similar situations in other projects/constructions and use them in your decision-making process									
5	Cooperate with colleagues to finish projects/constructions on time									
6	Guide less-experienced colleagues, whether in training courses or on day-to-day company/construction									
7	Learn new working techniques in workshops, seminars, and extension/specialization courses									
8	Learn new working techniques with fellow professionals from the same area									
9	Use new techniques you have learned in the companies where you currently work or have previously worked									
10	Define the use of new materials based on suppliers' offers									
11	Define the use of new materials based on their use in other projects/constructions									
12	Use materials and techniques according to your budget, disregarding environmental issues									
13	Use materials and techniques according to the project/construction environmental sustainability, disregarding implementation and maintenance costs									
14	Follow work models prescribed by hierarchical superiors									
15	Have goals and economic outcomes established by hierarchical superiors									
16	Wait for guidelines from a hierarchical superior when there is a problem in the project/construction									
17	Actively participate in research communities in their study area									
18	Participate in discussion groups on new work perspectives									
19	Encourage others to actively participate in professional communities									
20	Participate in multidisciplinary work teams									
C	**Innovation Competencies**									
1	Use technological tools for design (software/equipment)									
2	Use project management tools to control and execute projects									
3	Use Building Life Cycle Assessment Tools									
4	Check technical feasibility of alternative sources of energy in the project area									

5	Select suppliers and materials based on environmental sustainability									
6	Participate in the elaboration of systems of capture, reserve and reuse of rainwater, and gradual release of water surplus									
7	Check actions to mitigate possible environmental risks of the construction									
8	Act in order to promote the environmental certification of the project									
9	Use alternative energy sources in projects and constructions									
10	Follow the SINAT guidelines to verify the application of new techniques/materials									
11	Use new materials based on government requirements									
12	Use new materials based on reduced construction costs									
13	Use rainwater flow control techniques									
14	Use new materials for the maintenance of permeable areas in the vicinity of the construction site									
15	Propose new ways to implement the project in order to reduce waste and save money during production									
16	Propose new ways to implement the project, aiming at a cleaner/more eco-friendly production									
17	Propose new forms of work based on the experience of other colleagues in the same area (specialists/experts)									
18	Propose new forms of work based on experience gained in other companies (professional expertise)									
19	Propose new forms of work based on specific literature									
20	Propose new forms of work based on academic training									
21	Propose creative solutions not yet seen in the market									
22	Take initiative to solve problems in the course of the project/construction									
23	Use technology to present the expected end product to stakeholders									
24	Participate in professional networks									
D	**Customer-Related Competencies**									
1	Use new materials based on the criteria established by the customer, disregarding environmental issues									
2	Use new materials based on the reduction of water, power and gas consumption costs during the construction lifecycle									
3	Deliver project or construction with delay									
4	Choose solutions that reduce resource consumption in the phase of use (water, power, gas)									
5	Communicate project processes to stakeholders									
6	Deliver the project/construction on time, even if this implies in reduced quality of the end product									

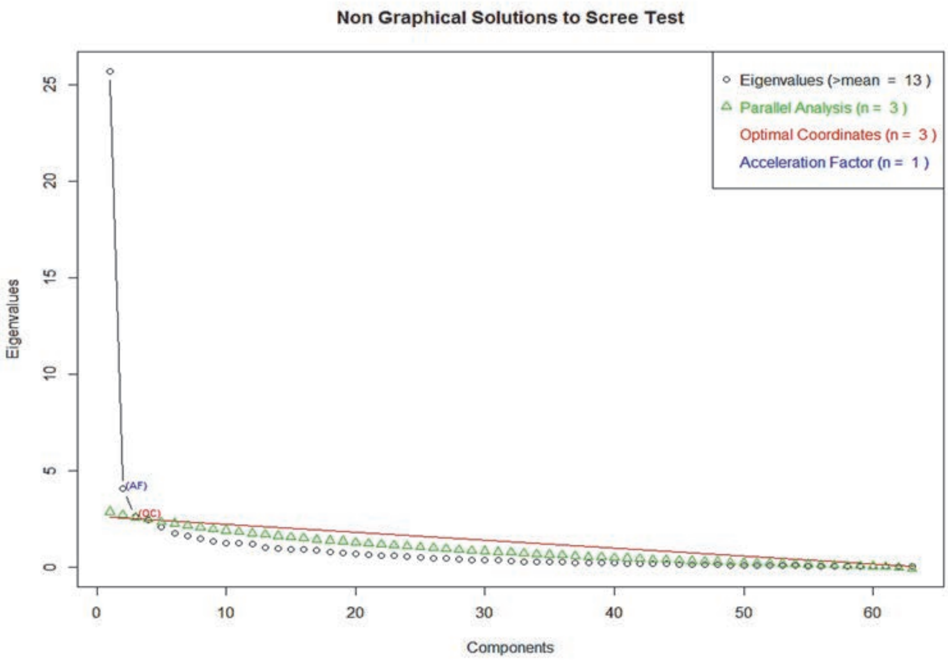


Fig. 2. Dimensionality test

Table 3. Reliability Indexes

Indicator	*Scale A*	*Scale B*	*Scale C*	*Scale D*	*Unified*
Cronbach´s alpha	0.92	0.90	0.95	0.74	0.97
Person Reliability	0.76	0.83	0.86	0.67	0.92
Reliability of Item	0.84	0.96	0.91	0.98	0.94

Overall, the reliability indexes supported an internal consistency ranging from acceptable to excellent. Problems in reliability were related to the person's reliability for dimensions A and D, when analyzed individually. The distribution of items between easy, medium and difficult was not uniform for dimension A. Dimension D adds noise to the measure when analyzed individually because of the small number of questions (Table 3).

It is worth noticing that, although the individual scales A and D have generated some noise in their dimensions, they did not affect the continuity of the study considering the unidimensionality of IACIS and its application as a single instrument. In terms of internal consistency, Cronbach's alpha indicates that the number of items (questions) and their correlation are excellent for the unified scale because their result was above 0.9. In the individual analysis, scale D was classified as acceptable, with results ranging between 0.7 and 0.8, despite its small number of items.

For the reliability of individuals, the values of the unified scale allow the characterization of subjects in 3 or 4 levels, which qualifies the scale as excellent. For item reliability, values greater than 0.80 are recommended. Lower values indicate that the sample size is not suitable to estimate the location of the items throughout the latent trait. Tables 4 and 5 show that this was not an issue.

3.3. Predictive adjustment of items and validity

Validity was analyzed considering the predictive adjustment, i.e., the items' ability to predict response patterns. The Winsteps software was used for infit and outfit statistical analyses. Infit (inlier-pattern-sensitive fit) statistics verifies the functioning of the item considering its predictive capacity for subjects considered targets – i.e., if subjects close to the location of the item respond within expected standards. Outfit (outlier-pattern-sensitive fit) statistics is sensitive to unexpected response patterns when the item is necessarily too easy or too difficult for the subject; it reflects the prediction of patterns when the subject is distant from the item. Infit and outfit values are characterized in mean-square (MNSQ) of predictive adjustment. MNSQ values are interpreted according to Linacre (2002):

(a) values below 0.50 are less productive for the measure, but do not degrade its operation;

(b) values between 0.50 and 1.50 are considered productive for the operation of the measure;

(c) values between 1.50 and 2.00 are considered non-productive for the measure, but do not degrade it; and

(d) values greater than 2.00 distort and degrade the measure.

Considering the predictive adjustment of infit and outfit only, most of the measures of dimensions A, B, C, and D were within the ideal functioning when analyzed as individual scales. In dimension A, the only items with borderline adjustments are related to the outfit: A1 (infit MNSQ = 1.30; outfit MNSQ = 1.66), A3 (infit MNSQ = 1.47; outfit MNSQ = 1.52), A12 (infit MNSQ = 1.50; outfit MNSQ = 1.65). While A1 was the question that required a lower level of trait, i.e, was very easy to answer, respondents considered A12 very difficult. A3 was considered intermediate, tending to difficult. Although these questions present predictive adjustments, they do not interfere in the measure and their maintenance in the set of questions is perfectly acceptable. For dimension B, borderline values were only detected for item B12 (infit MNSQ = 1.96; outfit MNSQ = 1.85) Values between 1.50 and 2.00 are considered non-productive for the measure, but do not degrade it.

Question B12 is particularly interesting because it was difficult for respondents (outfit MNSQ = 1.85). The question minimizes the importance of environmental sustainability in the project, while highlighting its economic aspects. Studies have shown the preponderance of the economic aspect to the detriment of the social and environmental aspects in the education of architects and engineers (MEC, 2018). However, several items evaluating environmental issues indicate that architects and engineers tend to consider the matter important.

The high infit value (1.96) means that the item performance was lower than expected for that target audience, potentially due to sample size or outliers. Data showed that 86% of respondents said they know about the subject, and 55% took environmental issues into consideration. Most of them considered environmental issues extremely important in the project budget (32.25%), and the remainder was well distributed in the other points of the scale.

Dimension C presented borderline adjustment for the following items:

- C10 (mnsq infit = 1.87; outfit MNSQ = 1.92), C11 (infit MNSQ = 1.69; outfit MNSQ = 1.65), C24 (Infit MNSQ = 1.51; outfit MNSQ = 1.88).

Items C10, C11 and C24 were also considered difficult. They are related to innovation competencies. Subjects' responses in the "Know" and "Already done" stage were:

- C10 – 43% know the SINAT guidelines, but only 18% have used them;
- C11 – 68% know new materials based on government requirements, and 40% have already used them;
- C24 – 98% know social networks for professional relationships, and 86% have already used them.

The SINAT (National Technical Evaluation System) guidelines are used by large corporations when a new product they would like to use is not standardized, or even in large-scale enterprises, especially the Brazilian low-incoming housing built with government funding. Until October 2016, 31 guidelines were issued; however, many of them deal with techniques already known to the public, which would justify their low use.

Question C24 presented a difficult-to-predict response pattern. Its result may be due to the number of respondents or the limitation of discrimination of the subject's level. Dimension D only presented adjustment problem for item D5 (Infit MNSQ = 0.81; outfit MNSQ = 1.57) "Communicate project processes to stakeholders". It was considered very easy by the respondents. Communication is one of the most requested competencies for architects and engineers for innovation and creativity (Martins and Martins, 2002; Simon, 2004).

When analyzing the unified scale, the following items presented borderline adjustment:

- B12 (infit MNSQ = 1.99; outfit MNSQ = 1.89), B13 (infit MNSQ = 1.55; outfit MNSQ = 1.59), B16 (infit MNSQ = 1.67; outfit MNSQ = 1.70), B19 (infit MNSQ = 1.06; outfit MNSQ = 1.52), D1 (infit MNSQ = 1.63; outfit MNSQ = 1.71).

Architects and engineers considered questions with greater decision complexity more difficult to answer, such as disregarding environmental issues in exchange for economic gains or seeking the environmental solution and not verifying its costs. The same happened with Autonomy (B16), seen as a necessity by all professionals, but that might be a problem depending on the organization in which the respondent works.

Encouraging colleagues (B19) is on the list of competencies of a professional who wants to see the organization he/she belongs to develop. It was considered very easy by respondents. It is cooperation, so often emphasized by several authors, which fosters innovation and productivity. According to the parameters, none of the borderline values indicate impairment of the measure or impairment of the scale. However, three items presented prohibitive adjustments, which would lead to a significant impairment in the functioning of the measure:

- C24 (infit MNSQ = 1.13; outfit MNSQ = 2.45), D3 (infit MNSQ = 2.25; outfit MNSQ = 2.29), D6 (infit MNSQ = 2.14; outfit MNSQ = 2.64).

These items were poor contributors to the reading and interpretation of the dimensions of "Innovation competencies" and "Customer-related competencies" in the unified scale.

However, they were maintained because the "quality X time" conundrum is common in the literature. Delays happen, but the purpose of management and control is to achieve successful planning, minimizing delays and their impacts. Although these issues have been problematic in the unified scale, it is important to highlight that the same did not happen in the individual analysis of dimension D.

3.4. Scalability

Scalability consisted of verifying the latent trait as a single continuum on which subjects and items were located. Our study deals with a Likert-type response model; therefore, item location indicates the level of skill from which a subject is equally capable of marking the smallest and largest possible category of the Likert scale.

Here, dimensions A, B, C, and D, as well as the unified format, presented similar properties in at least two aspects:

I. The scales usually tended to higher sensitivity at levels of near-zero trait, and the C scale presented the best information distribution, considering the test information function (TIF), while the D dimension showed the worst level of information. TIF indicates in which portions of the latent trait the scales aggregate more information. The peaks of the graphs indicate the areas to which the instrument is most sensitive (Fig. 3 and Fig. 4).

II. In spite of the good distribution of subjects in the latent trait, the answers to the questions indicate a higher concentration at the lower level of the trait measured (Fig. 5), indicating that the sample shows the studied behavior more easily.

An item that demanded a higher level of trait received the lowest score on the scale and was therefore less important for the professional characteristics desired by architects and engineers. Respondents tended to answer known items easily, and these items were considered more important for the professional profile because they were familiar to those who work in the area under analysis.

For dimension A, three items required a lower level of trait: A1; A6; A2 (Table 4).

These issues are part of the basic repertoire of architecture and engineering; there is no great challenge or difficulty, so a lower trait level. However, every measuring instrument must be constructed from the basic to the most advanced questions (Pasquali, 2011). The items that required the highest level of trait were A12, A4, and A3. The questions that demanded the highest ability from respondents were specific to the environment. In the process of validating these questions, the professionals' difficulty to understand the relevance of environmental issues became apparent. In Dimension B, the three items with the lowest trait level requirements were B7, B8, and B9. The conventional and organizational learning process was the most easily chosen by respondents.

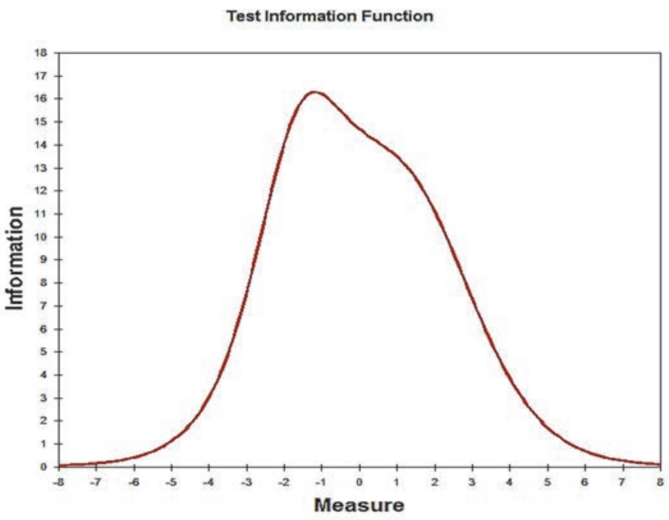


Fig. 3. TIF for scale C

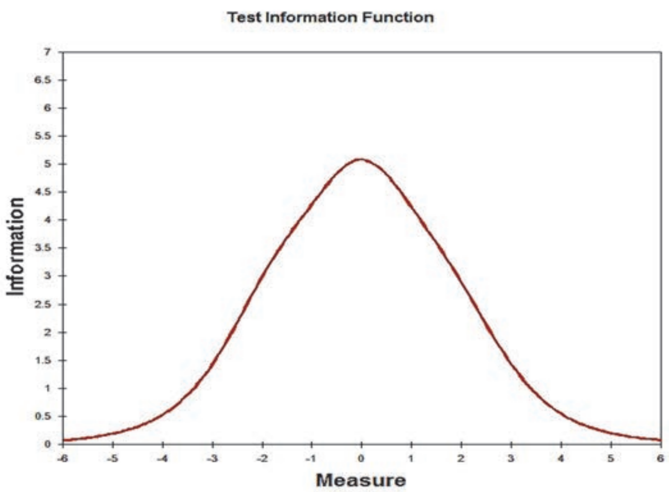


Fig. 4. TIF for scale D

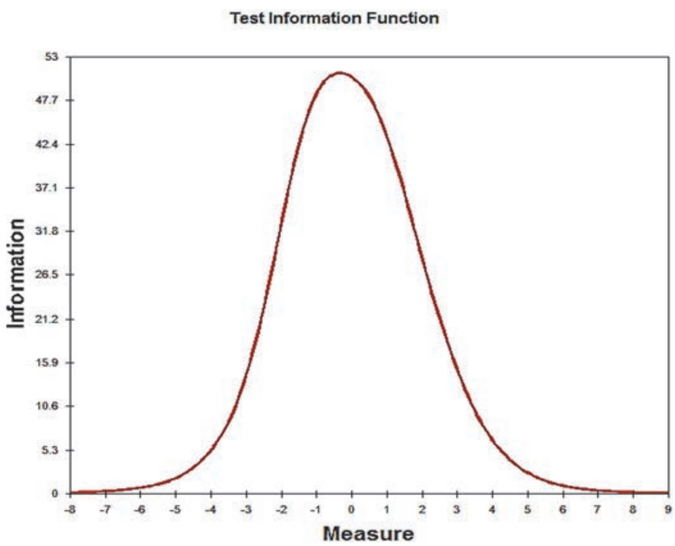


Fig. 5. TIF for the unified scale

Table 4. Location of items by trait level in logits for items of scales A and B

Location of items in logit by scale					
Item	***Unified***	***Scale A***	***Scale B***	***Scale C***	***Scale D***
A1	-0.75	-0.68	-	-	-
A2	-0.43	-0.28	-	-	-
A3	0.07	0.36	-	-	-
A4	0.47	0.88	-	-	-
A5	-0.25	-0.05	-	-	-
A6	-0.60	-0.49	-	-	-
A7	-0.40	-0.24	-	-	-
A8	-0.35	-0.18	-	-	-
A9	-0.43	-0.28	-	-	-
A10	-0.22	-0.02	-	-	-
A11	-0.35	-0.18	-	-	-
A12	0.56	1.00	-	-	-
A13	-0.11	0.14	-	-	-
B1	-0.38	-	-0.43	-	-
B2	-0.51	-	-0.56	-	-
B3	0.34	-	0.29	-	-
B4	-0.30	-	-0.35	-	-
B5	-0.48	-	-0.54	-	-
B6	-0.72	-	-0.77	-	-
B7	-1.22	-	-1.28	-	-
B8	-0.95	-	-1.01	-	-
B9	-0.78	-	-0.84	-	-
B10	0.90	-	0.86	-	-
B11	0.16	-	0.11	-	-
B12	1.33	-	1.31	-	-
B13	1.04	-	1.01	-	-
B14	1.09	-	1.06	-	-
B15	0.72	-	0.69	-	-
B16	1.14	-	1.11	-	-
B17	-0.40	-	-0.45	-	-
B18	0.09	-	0.04	-	-
B19	0.26	-	0.21	-	-
B20	-0.43	-	-0.48	-	-

The most demanding questions of competencies have shown that architects and engineers have difficulty accepting hierarchical relationships, perhaps because of their origins as independent professionals, which many of them still are at present. That also explains their autonomy of action, a competency desired by all. Environmental issues are once again positive, as they are taken into consideration when choosing materials and techniques, according to questions B12, B16, and B14. In Dimension C, the three items with the lowest trait requirement were C1, C22, and C18.

The items proved to be very coherent with the studies. Technological tools for design (design, structural calculations, energy calculations, lighting, project management, etc.) are frequently used and make professionals' daily lives easier.

Initiative and autonomy are among the most desired competencies. Acquired knowledge is also part of the management of competencies, and adds value to the subjects' work. It is part the individual's lifelong education. The items with the highest trait requirement were the same with problematic adjustment discussed previously: C11, C10, C24. In dimension D, isolated mapping does not contribute to the understanding of the measure in the same way as in the others, depending on the restricted number of items. However, the most difficult items were competencies D1, D3, D6. Items D3 and D6 presented prohibitive adjustments, as previously described. These questions measure the level of precision: the quality of the final product, the zeal and promptness in customer service, the deadline and the scope. This competency is also known as professionalism.

Table 5. Location of items by trait level in logits for items of scales C and D

Location of items in logit by scale					
Item	***Unified***	***Scale A***	***Scale B***	***Scale C***	***Scale D***
C1	-0.81	-	-	-0.95	-
C2	-0.43	-	-	-0.47	-
C3	0.11	-	-	0.23	-
C4	-0.08	-	-	-0.03	-
C5	-0.06	-	-	0.00	-

C6	-0.40	-	-	-0.44	-
C7	-0.20	-	-	-0.18	-
C8	0.09	-	-	0.20	-
C9	-0.27	-	-	-0.27	-
C10	1.14	-	-	1.57	-
C11	1.17	-	-	1.62	-
C12	0.16	-	-	0.28	-
C13	0.22	-	-	0.36	-
C14	0.22	-	-	0.36	-
C15	-0.43	-	-	-0.47	-
C16	-0.40	-	-	-0.44	-
C17	-0.25	-	-	-0.24	-
C18	-0.60	-	-	-0.68	-
C19	-0.04	-	-	0.03	-
C20	-0.08	-	-	-0.03	-
C21	0.03	-	-	0.11	-
C22	-0.62	-	-	-0.72	-
C23	-0.25	-	-	-0.24	-
C24	0.26	-	-	0.41	-
D1	1.87	-	-	-	1.22
D2	-0.43	-	-	-	-0.92
D3	1.42	-	-	-	0.79
D4	-0.25	-	-	-	-0.76
D5	-0.51	-	-	-	-0.99
D6	1.28	-	-	-	0.66

An analysis of the distribution of items in the unified scale contributes to understanding how the competencies listed in the elaboration of the instruments relate to each other. Considering the unified measure, the five most difficult items, or that demanded a higher level of trait (excluding those with impeditive adjustments) were D1, B12, C11, C10, and B16. The items with the lowest level of difficulty or trait were B7, B8, C1, B9, and A1. All items were analyzed previously.

Fig. 6 shows the predominance of scale B items in the upper portion of the trait, i.e., respondents considered these items less important. In the Profession Competencies Dimension, respondents considered 10 out of 13 items very important. "Participate in the elaboration of a construction waste management plan by enterprise" and " Choose materials disregarding environmental certification" were classified as less important. "Using the atlas and solar plants to define free spans, lighting and ventilation systems, energy systems" (A3) was classified as intermediate. Items in this group might show higher levels of difficulty.

The Organizational Competencies dimension was more balanced: 10 out of 20 items were considered less important. Here, we highlight the items "Define the use of new materials based on suppliers' offers" and "Define the use of new materials based on their use in other projects/constructions" because these questions contradict the studies, which demonstrated that the construction industry innovates largely by the influence of the products offered by suppliers, the monitoring of market trends and the observation of competition.

Innovation Competencies (Dimension C), included 11 questions considered more important by architects and engineers, and 5 questions were considered intermediate. Out of the 24 questions, 1/3 were considered unimportant, such as "Use the Building Life Cycle Assessment Tools," "Act to promote the environmental certification of the project" and "Follow the SINAT guidelines to verify the application of new techniques/materials".

Although 61% of respondents know LCA tools, only 17% have used them in their projects. This might be explained by the fact that LCA requires an extensive database, including average city temperature, energy sources, CO^2 emission and thermal transmittance of materials, among other requirements that are currently being mapped in Brazil and will soon be available, free of charge, according to the Brazilian Program of Life Cycle Assessment (PBACV, 2012). The tools available today are costly.

The environmental certification of a project is optional and adds value to the enterprise. It usually requires good analysis of the cost-benefit ratio and the return time of the investment; the cost of certification itself must be added to the extra expense associated with the use of sustainable materials and techniques, which are 5% to 10 % more expensive that their traditional counterparts. The SINAT guidelines are often subject to criticism; however, when observing the new products and techniques detailed in the manuals, architects and engineers have the opportunity to extrapolate this information to their projects/constructions. Research shows that the education of these professionals is usually based on conventional models of teaching and learning.

Dimension D, the last item in our scale, dealt with the client-related competencies. Here, at least 3 items were considered very important. The item that stood out was "Choose solutions that reduce resource consumption in the phase of use (water, power, gas)".

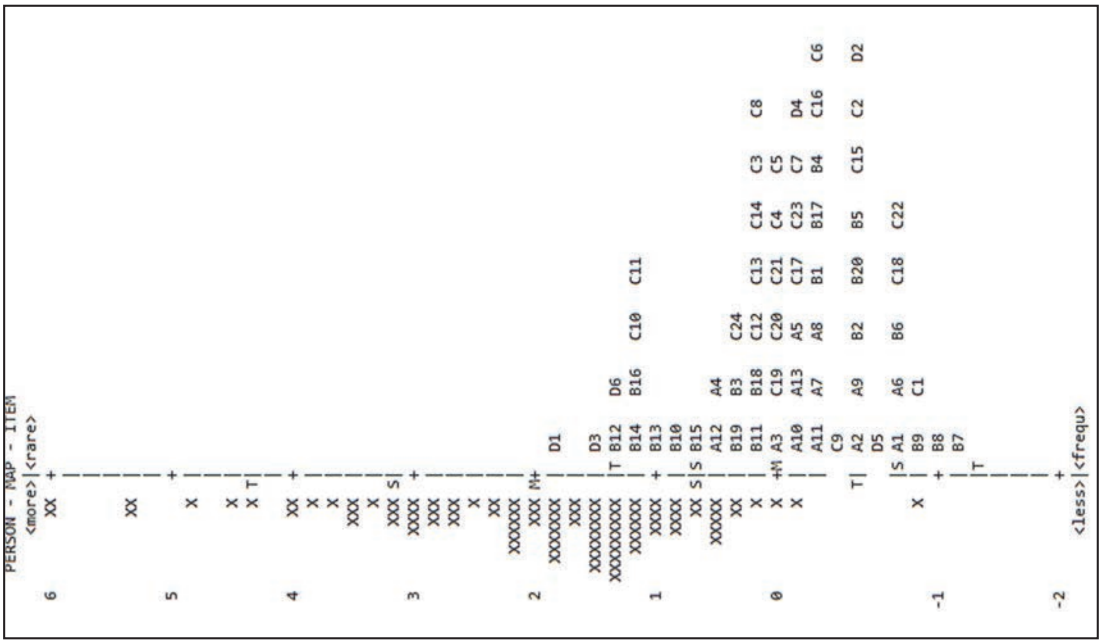


Fig. 6. Map of items (upper portion of the chart) and people (lower portion) on a unified scale. Each "X" represents one subject of the sample

A building has an approximate lifespan of 80 years. By choosing solutions that reduce resource consumption, these professionals choose environmental sustainability. In this case, the economic perspective lies in the long-term gains for the client, which are associated to the savings in terms of resources.

In the short and medium-term, professionals who make this choice become a reference to customers. Finally, we obtained a correlation matrix between the estimated trait levels for the subjects for each scale. We observed that our study participants represent the four structures as highly correlated with each other (Table 6). The correlations again suggest that the set of items may be used as a unified scale. Thus, IACIS was validated by respondents and approved for broad use.

4. Conclusions

To assess competencies, we need to measure behaviors in the face of situations. Therefore, a psychological measure that validates the evaluation instrument is required. One of the highlights of our study is that it uses well-known psychometric characteristics, which are not part of most measures elaborated in management studies; without them, it is more difficult to know what exactly the instruments are evaluating. By ignoring the quality of the assessment, decisions based on these instruments become meaningless.

The use of the IRT is another advantage, because it is a theoretical landmark in psychological measures; it allows us to compare items together with the position of the subjects in the latent trait. In summary, we evaluated the professional's ability to answer questions, as well as the level of difficulty of each question. We identified subjects who were able to answer the most difficult questions, and whether or not their answers were successful. This allowed us to identify improvements or changes to be made in the research instrument.

We were also able to visualize in which latent trait levels there was more noise due to measurement errors. Instruments of this type are commonly used for personnel selection; therefore, being aware of the errors of the measure allows you to understand in which setting the instrument would work better, whether in screening or selection, for example. The person who chooses to use the instrument should be the one to decide on the setting where it will be used, because they are the ones who must define what characteristics they expect to find or would like to learn about.

Table 6. Correlation matrix between competency scales A, B, C and D

Correlation Matrix				
	A	**B**	**C**	**D**
A	1.00			
B	0.77**	1.00		
C	0.78**	0.79**	1.00	
D	0.68**	0.73**	0.66**	1.00
Significance levels: *p<0.05; **p<0.001				

One of the challenges of our study was to identify professionals that would fit the profile established in our methodology, which effected our sample size. Procedures such as dimensionality analysis and IRT usually require 100 subjects per dimension, or 10 subjects per item. We performed our analyses with fewer subjects; therefore, we chose more robust procedures and a more rigorous analysis of error and reliability parameters, which allowed us to state that the instrument is reliable, and accurately evaluates what it proposes.

A great challenge to create IACIS was to define the expected behaviors from a theoretical field that offers few clues for the operationalization of such behaviors. The parameters for the theory of environmental innovation for the engineering and architectural market are still poorly defined; therefore, our scale contributes by shedding some light on the subject. The analysis of the subjects highlights the barriers that environmental innovation in Brazil must still overcome. The changes in professional profiles can be understood as consequence of a restructuring process that includes training, market, and government.

Our research developed and validated the scale. Here, we provide an opportunity for other researchers to develop their own scales, replicating our path with the necessary transcultural adaptations. In further studies, we intend to show how IACIS should be applied and interpreted.

Acknowledgments

The study is an integral part of a PhD research project being carried out at Fluminense Federal University. The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and all the experts who answered the survey.

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