

Measuring organizational effectiveness in information and communication technology companies using item response theory

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Abstract. The aim of this paper is to measure the effectiveness of the organizations Information and Communication Technology (ICT) from the point of view of the manager, using Item Response Theory (IRT). There is a need to verify the effectiveness of these organizations which are normally associated to complex, dynamic, and competitive environments. In academic literature, there is disagreement surrounding the concept of organizational effectiveness and its measurement. A construct was elaborated based on dimensions of effectiveness towards the construction of the items of the questionnaire which submitted to specialists for evaluation. It demonstrated itself to be viable in measuring organizational effectiveness of ICT companies under the point of view of a manager through using Two-Parameter Logistic Model (2PLM) of the IRT. This modeling permits us to evaluate the quality and property of each item placed within a single scale: items and respondents, which is not possible when using other similar tools.

Keywords: item response theory, two-parameter logistic model, information and communication technology sector, strategy

1. Introduction

Organizational needs for survival and/or growth – whether through the globalization of markets, inspiration of a visionary entrepreneur, or even through the needs of its stakeholders – are frequently mentioned concerns within organizational literature and practice. After all, in an extremely competitive environment, it is not enough to demonstrate efficiency in processes and in attaining results. Organizations must demonstrate effectiveness in analyzing contingencies, defining strategies and structures to reach their goals, and consistency over time in the continuous search to guarantee the business existence and growth.

Organizations are open systems in continuous interaction with their business environment. They go through adaptation processes and are likely to present organizational dysfunctions which in turn reflect in their performance [24]. To Bertalanffy [38] a system

is an entity which has the capacity to maintain a certain level of organization in the face of internal or external changes, composed of a set of elements which interact with each other according to determined laws in order to attain a specific objective.

The aim of this paper is to measure the effectiveness of the organizations Information and Communication Technology (ICT) from the point of view of the manager, using Item Response Theory (IRT). It is necessary to verify the effectiveness of these organizations, which are normally associated with complex, dynamics and competitive environments. In this context, organizational design is focused upon the design of three core dimensions: complexity, formalization and centralization [24].

“The basic precept is that the organizational design configurations begin at the macro, organizational level. Then, the design configuration is carried down to the microlevel. This open system operates within a dynamic and sometimes turbulent external environment. The personnel

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subsystem then is defined by those who do the work. The technological sub-system is defined by how the work is accomplished [8, pp. 83].

The organizational effectiveness, in this article is aligned to [62, 30, 53]. The organizational effectiveness is related to the "business" (with or without profit) and it is considered in terms of the sensitivity of the organization in relation to its business environment, representing the ability to learn, adapt and respond to market demands. The mission of an organization is an element to guide their strategic issues; it is a larger goal, from which all other goals are derived.

However, in the literature there is discordance between the concept of organizational effectiveness and its measurement. Consequently, a theoretical construct was created to evaluate organizational effectiveness with base in Johnson et al [21, 58] in order to identify items for the preparation of the questionnaire, that it was submitted to experts. The assessment of organizational effectiveness was made by 80 (eighty) managers from ICT companies, that participated in the survey.

This is the purpose of this paper, put ergonomics in a strategic scope. Ergonomics should contribute more directly to business strategy and in the same language (macroergonomics). According Dul and Neumann [28, pp. 746]: "Also it will be easier to obtain health and safety improvements, if managers understand that the ergonomic improvements will simultaneously help them realize their primary strategic business goals".

2. Methodological formulation

2.1. Item Response Theory (IRT)

IRT is an amply used tool in education and psychology [12] and has been applied to other areas, such as medicine [67, 22, 27, 65]; marketing [60; 32]; services [39]; information systems [59]; genetics [23]; organizational effectiveness [23] and others. In general, IRT is a set of mathematical models which seeks to measure latent traits, characteristics which cannot be directly measured. IRT does this by means of a grouping a set of items and constructing a scale in which the respondents' respective latent traits can be compared with each item's difficulty [20, 52, 12].

For Reckase [40], one advantage of the IRT in the face of other tools destined to measure latent traits such as the Classical Test Theory (CTT), is that IRT focuses of an item's characteristics and their combi-

nations within the test as a whole. CTT assumes that the test is already constructed and focuses on the score, in other words on the individual. This leaves the IRT focusing on the items and the CTT focusing on the score. For Hays et al. [49], this advantage permits the creation of a scale in which responding parties and items are allocated on the same continuum. One of the CTT's limitations is the proficiency of the respondents and the difficulty of the items which cannot be separately estimated. Beyond this, merely one reliability estimate is generated at a standard deviation from corresponding measurements in the CTT, while each item in the IRT is treated individually and possesses a specific error for each separately. In general, IRT models are presented by means of a logistic function.

One of the most widely used IRT models for items with dichotomous and cumulative responses is the two-parameter logistic model (2PLM) developed by Birnbaum [1] and based on Lord [18], which is represented by the following equation.

$$P(\theta_j, a_i, b_i) = \frac{1}{1 + e^{-a_i(\theta_j - b_i)}}$$

b_i is the difficulty parameter of item i represented on the same scale as the latent trait θ_j , and a_i is the discrimination (or inclination) parameter of item i . Usually, the quantity of b is represented on a scale with mean zero and standard deviation one. The Item Characteristic Curve (ICC) represents the $P(\theta_j, a_i, b_i)$ relationship with respect to the probability of a certain response to an item, the respondent's latent traits and the item's parameters [59, pp. 168].

2.2. Methodological proceeds

The questionnaire was sent to all the associated companies registered in the principle entities which congregate organizations of this sector: ACATE – Santa Catarina Technology Companies Association; ASSESPRO – Association for Brazilian Information and Technology Companies and CELTA – Business Center for Elaborating Advanced Technologies.

Information and Communication Technology companies, or "ICT" originated from the computer and telecommunications industry. Technological advancements in microelectronics and telecommunications have culminated in the development of integrated circuits, which have increased access to the user facility advantages of micro computers as well as perfections in satellite communications and fiber

optics, telecommunications advancements which have linked users around the globe. In initial production of micro computers in the 1970s; predominant micro computer production in the 1980s; and strong expansion in the 1990s in large part to the world wide web, which connects the current global and installed base of computers [19, 3].

In all, of the 550 companies to which the questionnaire was sent, 80 responded, corresponding to a 14.55% rate of return. This study adopted the following methodological steps in elaborating the questionnaire: (1) primary elaboration of the items of the construct, (2) content analysis of the items with validation by specialists (ICT company managers and Phd. Professors), (3) application of the questionnaire in a pilot sample in order to verify data consistency. For the sample composed of 9 ICT company managers, results were considered consistent. Psychometrics techniques were used in elaborating the questionnaire. Validity is referred to the instrument measuring what it proposes to measure (in order to be valid, it must be reliable). Validity is the “degree to which test scores are related to some external criteria of the same test.” As to reliability, there must be consistency among the scores of the instrument when comparing them to results of the same or a similar test upon being submitted at another opportunity to the same group of results of an instrument hypothetically applied simultaneously (the pilot sample was carried out seeking to verify the consistency of the data). The relationship between validity and reliability is the

contrast in terms of consistency, which considers external (validity) and internal (reliability) criteria [54, pp. 174].

The questionnaire seeks to measure management perceptions with respect to organizational effectiveness as a subtest. It is considered to have valid questions with respect to content and the instrument is reliable, as characterized by knowledgeable judges. The subtest evaluates the organizational effectiveness of the organization where the manager works as referenced by its organizational environment factors with general environment factors adapted from Johnson et al [21] Pestel model and task environment factors based on Daft [56]. However, the models are restricted representations of the given reality and have the indispensable condition of adapting to attend the basic presupposition of an investigation. The questionnaire presents the items, as shown in Figure 1, submitted to ICT company managers. Initially, the questionnaire presented a Likert scale and contained five response categories: SD (Strongly Disagree); D (Disagree); NA/ND (Neither Agree Nor Disagree); A (Agree); and SA (Strongly Agree). However, after treating the data with the IRT – due to the low frequency of responses in the categories and considering the number of observations (merely 80 managers) – the responses were grouped into two categories: into category 1 called Agree (A-Agree and SA-Strongly Agree) and into category 2 Disagree (SD-Strongly Disagree; D-Disagree; NA/ND-Neither Agree Nor Disagree).

| | |
|--|--|
| 1. The company follows formalized Strategic Planning. | 2. The company's market competition is elevated. |
| 3. The company possesses a great variety of clients. | 4. The market where the company enacts is diversified. |
| 5. The company possesses product diversification. | 6. The company takes society into consideration when planning its actions. |
| 7. The company analyzes its independence with respect to suppliers. | 8. The company analyzes the dynamic of the economy in planning its actions. |
| 9. The company considers the influence of regulatory group performance on its actions. | 10. Technology is a fundamental variable in company planning. |
| 11. The company evaluates its cycle of life and innovation to its products per market demands. | 12. The company stimulates partnership policies with other companies in order to attain strategic collaboration. |
| 13. The company evaluates its market image. | 14. Innovation is a strategic focus for the company. |
| 15. The company evaluates the possible environmental/ecological impact of its actions. | 16. The political scenario is analyzed as to its influence in company actions. |

Figure 1 - Items of the questionnaire submitted to managers. Source: Elaborated by the authors.

3. Organizational effectiveness

The emergence of concerns over organizational results, which can be considered the basis for the effectiveness construct, is presented in the work of Adam

Smith in his famous publication, “The Wealth of Nations” (1776) and in Taylor’s Scientific Management [34]. First, there is concern with efficiency and efficacy, to arrive at effectiveness. These terms must possess differentiated scopes; however, organizational effectiveness is still used in the realm of efficiency and efficacy.

Radner [58] affirms that being effective signifies possessing the competency to outline and implement good strategies. For Marinho and Façanha [6, pp. 6] statement: “Organizations are effective when their decisive criteria and their achievements point to permanence, structure true objectives, and construct trustworthy rules of conduct endowed with credibility towards those who make up the organization and their performance environment.” McCann [30, pp. 43] says: “Organizational effectiveness has always measured how successfully organizations achieve their missions through their core strategies.”

Kushner [53, pp. 11] explains “We define organizational effectiveness as continued success in carrying out an organization’s mission,” while for Burke [62], non-profitable organizational effectiveness is evaluated by the ability to complete one’s socially defined mission. In this article, organizational effectiveness is taken to signify “doing the right thing over time,” with results corresponding to guaranteeing the business. The definition used here is aligned with the work of Burke [62], McCann [30], and Kushner [53], relating the “business” (either for profit or non-profit) to its environment, representing the capacity to learn and adapt and respond to market demands. The mission of an organization is its guiding principle in answering strategic questions. It deals with a greater goal for the organization, to which all others are tied in their existence in the external environment, demonstrating the strategic scope inherent to the concept of effectiveness. Organizational effectiveness depends upon how organizations orient themselves with respect to external environment forces [17, 14].

For Balduck and Buelens [5] organizational effectiveness is one of the basic constructs of organizational theory. These authors look to Goodman and Pennings [46] to affirm that effectiveness is central to studying organizational analysis and organization theory must include the study of this construct, even with the controversy over what it constitutes and how it should be measured. Evaluating effectiveness is based observing the concepts that compose it [48]. Organizations possess multiple objectives to be attained, considering their limited resources and conflicts of interests among the groups that compose them, demonstrating a lack of consensus among academics both with respect to the concept of effectiveness and to criteria for its evaluation, even with incessant research towards these questions [9, 13, 35; 10]. However, in order to adopt a conceptual reference, one resort to a strategic position focused on the general environment and the task and related to the Contingency School. In the beginning of the 21st cen-

tury, one observes a tendency to align effectiveness not only to profit-related goals, but to organizations’ missions.

The models to analyze organizational performance environments are innumerable. In order to perform such analysis, managers may adopt one or a mixture of these to prospect scenarios. Among them are Porter’s five forces [42]; Porter’s diamond [41]; Gunther’s competition cycles [51]; and Swot Analysis as conceived by Humphrey, which corresponds to Strengths, Weaknesses, Opportunities, and Threats [43]. For the purposes of this article, the Pestel model [21] provides macro-environmental analysis in considering six factors: Political, Economic, Social, Technological, Environmental, and Legal. However, one must also consider the environment of the task, and to this end, was used the classification of Daft (2008): Competitors, Customers, Suppliers, Customers/Users, Partners and Regulators.

The examples of Sowa et al. [29], [44], [47] show that organizational effectiveness integrates innumerable other concepts and has evolved into a construct. There is a proliferation of studies on ideal organizational types, but the conflict concerning such an ideal has given origin to a “contingency model.” There are many authors worthy of highlight for such an approach, such as Burns and Stalker [63]; Lawrence and Lorsch [45]; Van de Ven and Ferry [4]. In their view effectiveness evaluations differ according to environmental circumstances. Under such a perspective, effectiveness depends then on correspondence among an organization’s attributes and its environmental conditions, thus deserving the denomination of contingency approach. The Figure 2 presents a summary of the historical considerations of the concept of organizational effectiveness.

One must consider the concern for stakeholders’ demands and the necessary adaptation on the part of organizations in responding to such demands. The focus is on transactions beyond organizational boundaries and their interactions with multiple constituents [46, 64, 7]. In this article a contingency focus is adopted for how environmental factors affect organizational effectiveness. The constituent under analysis is the manager and his/her perception with respect to the effectiveness of the organization of which he/she is part.

In order to do so, the IRT is used towards the objective of measuring organizational effectiveness in ICT companies, from a managers’ perspective.

| Authors and their time-frame | Perception of organizational effectiveness |
|---|---|
| 1950s Likert [57] | It is not enough to measure the morale and attitudes of an organization's employees. Effectiveness is based on multiple objectives criteria. |
| Bronowski [26] | Personal satisfaction and effectiveness are related: to the degree that satisfaction increases, effectiveness increases. |
| 1960s Burns e Stalker [63] | Systematic thought provides the foundation for diverse new perspectives: the Contingency Theory, in which the importance of strategy is highlighted and structure are adjusted as determinants of performance. |
| Katz e Khan [13] | The organization is an open and dynamic system. |
| 1970s Pfeffer e Salancick [31] | Effective organizations possess resource interdependence and respond to the needs of the groups which control these resources. |
| Reddin [66] | Organizations have life cycles like those of humans. An effective organization is that capable of adapting to changes in its environment. |
| 1980s Weick e Daft [34] | It depends on the capacity of managers to know how to interpret and understand the messages supplied by workers and through organizational means in which they develop their tasks, as well as the insight they have to detect and recognize the limits of their actions in this means. |
| Quinn e Rohrbaugh [50] | Scientific studies are geared to models, for example the <i>Competing Value Framework</i> . |
| 1990s Brunet et al. [37] | One observes investigations referring to the organizational effectiveness construct. Defining organizational effectiveness in a manner which is universally accepted is a difficult task. |
| Banner e Gagn c [15] | The topic of organizational effectiveness is surrounding by ambiguity and confusion. |
| Thibodeaux e Favilla [44] | There is not yet a universal theory on the theme. |
| First decade of 2000 Kushner [53] | Continued success in carrying out an organization's mission. |
| McCann [30] | The success that organizations have in achieving their mission through its core or essential strategies. |
| Sowa et al [29] | Study organizational effectiveness in non-profit organizations. |
| Balduck e Buelens [5] | Revise the concept effectiveness and investigate the distinctive characteristics between effective and non-effective organizations. |
| Burke [62] | Non-profit organizations' effectiveness is evaluated by their ability to carry out their socially-defined mission. |

Figure 2 - History of organizational effectiveness

4. Results and discussion

Table 1 show the parameters estimated for the 16 items based on a sample of 80 managers of ICT companies in a scale with zero mean standard deviation 1. It is observed that the ordering of items according to the degree of difficulty is represented by the parameter b.

In practical terms, based on the parameter b, is more likely that a manager who has a perception of effectiveness of your business around -2.000, agrees with the items 10 (-4.199) 14 (-3.149) 11 (-2.653) and 08 (-2.632). It is likely that he does not agree with the other items once they are above their perceived degree of effectiveness. Item 10 has a lower degree of difficulty that the item 13 (-1.746), because the item 10 is related to technology, A subject that is inherent in ICT companies (Information and Communication Technology), while item 13 "The company evaluates its market

image" seems not to be the focus of concern manager, which justifies the position of items.

Still based on the degree of difficulty, it appears that the manager tends to have greater agreement with concerns about innovation, items 11 (-2.653) and 14 (-3.149), respectively, than items 6 (- 1.222) and 15 (-0.324), relating to society and the environment.

Regarding the analysis of the latent trait (degree of effectiveness of the company based on the perception of the manager), as Table 2 show that, when selecting managers who responded to all 16 items, for example, the manager G13 and G20, observed that the degree of proficiency or effectiveness of these respondents is different, even if they agreed with 10 items, whereas the agreement took place on different items. The G20 has a higher proficiency (higher degree of effectiveness) than the G13. This feature proves an advantage of Item Response Theory (IRT) in comparison to the Classical Test Theory (CTT), because it was considered the assumptions of TCT, the conclusion is that they have the same score,

because the TCT is not positioned item and respondent on the same scale.

Table 1

Parameters of the items

| | a | b |
|---------|-------|--------|
| Item 10 | 0.821 | -4.199 |
| Item 14 | 1.024 | -3.149 |
| Item 11 | 0.679 | -2.653 |
| Item 08 | 0.863 | -2.632 |
| Item 07 | 0.643 | -1.899 |
| Item 13 | 0.710 | -1.746 |
| Item 12 | 0.867 | -1.736 |
| Item 02 | 1.025 | -1.648 |
| Item 09 | 1.092 | -1.255 |
| Item 06 | 0.777 | -1.222 |
| Item 01 | 0.930 | -1.101 |
| Item 03 | 1.166 | -1.081 |
| Item 16 | 0.793 | -0.596 |
| Item 04 | 0.913 | -0.365 |
| Item 15 | 0.841 | -0.324 |
| Item 05 | 0.941 | 0.003 |

Table 2

Estimates of the degree of effectiveness for some respondents

| Gestor | Núm. Itens Respondidos | Itens Respondidos Positivamente | % Acertos | Grau de Efetividade | Standard Error | Itens de Concordância |
|--------|------------------------|---------------------------------|-----------|---------------------|----------------|-------------------------------------|
| G1 | 16 | 7 | 43.75 | -1.326 | 0.520 | 2;8;9;10;12;13;16 |
| G2 | 16 | 8 | 50.00 | -1.245 | 0.522 | 6;7;8;10;11;12;14;16 |
| G3 | 16 | 15 | 93.75 | 1.064 | 0.676 | 1;2;3;4;5;6;7;8;9;10;11;12;14;15;16 |
| G13 | 16 | 10 | 62.50 | -0.776 | 0.544 | 1;2;6;7;8;10;11;12;13;16 |
| G20 | 16 | 10 | 62.50 | -0.459 | 0.546 | 1;2;3;8;9;10;11;12;13;14 |

5. Conclusion

Based on the results obtained, one can verify the viability of measuring the organizational effectiveness of ICT companies from the perspective of management using the IRT. The IRT presented several advantages with respect to selecting items which made up the questionnaire as it permits quality and property evaluations for each individual item involved in the study and places items and responses within a single scale, going beyond the limitations of other analysis tools. The study carried out herein showed itself to be particularly useful in evaluating individual constructs that are otherwise difficult to observe and extract, such as management perceptions of organizational effectiveness. One must highlight that due to the fact of utilizing the IRT, there is also the advantage of providing internal information from the items, which permits us to verify the positioning

with respect to company degree of effectiveness. For example, the item 10 has a lower degree of difficulty than the item 13 (-1.746), because the item 10 is related to technology, an issue inherent in this sector (Information and Communication Technology companies), while item 13, referring to the image of company in the market seems not to be the focus of concern manager, which justifies the position of items.

Measuring effectiveness among Information and Communication Technology companies also proved to be viable with the utilization of the Item Response Theory and the Samejima Graded Response Model (GRM) de Samejima [16], according to a study of Trierweiler et al [2]. However, it is suggested that other models be applied, for example, the multidimensional models [40].

One advantage of Item Response Theory in comparison to the classical theory of tests is that the Item Response Theory allows estimating the degree

of organizational effectiveness based on a scale, Table 2 shows that, when selecting managers who responded to all 16 items, for example, the manager G13 and G20 observed that the degree of proficiency or effectiveness of these respondents is different, even if they agreed with 10 items, whereas the agreement took place on different items. The G20 has a higher proficiency (higher degree of effectiveness) than the G13. This feature proves an advantage of Item Response Theory (IRT) in comparison to the Classical Test Theory (CTT), because it was considered the assumptions of CTT, the conclusion is that they have the same score, because the CTT is not positioned item and respondent on the same scale.

As to the limitations of the organizational effectiveness questionnaire, presented in Figure 1 of this article, it is suggested the construction of a greater number of items as well as submitting them to a larger sample of management respondents. After amplifying the instrument, it is suggested that it applied to other stakeholders as well as ICT companies from other regions of Brazil in order to perfect the instrument, seeking greater representation of the segment analyzed.

Finally, this article does not present a definitive tool for application, since more items are necessary to increase its survey, including the consideration of other regions in Brazil and other countries.

It would also be interesting to build a computerized adaptive test (CAT) for the respondent (manager) – the end of the questionnaire – get, immediately, the degree of effectiveness of your company. As such, a greater reach of the instrument should be considered with the objective to contribute to business management in the ICT sector through measuring the effectiveness of these organizations.

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