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# Multicriteria Model for Organizational Green Information Technology Maturity Assessment and Benchmarking: Defining a Class Structure †

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**Abstract:** Assessing Green Information Technology (IT) maturity in organizations is a relevant process to measure the progress of sustainable IT initiatives and to support new actions to improve them. Knowledge about the organizational maturity level in Green IT and comparing this level with those of other companies are necessary for self-assessment to strengthen organizations' general sustainability strategy. The main objective of this paper is to communicate a Green IT maturity assessment model with its class structure. This model can also provide benchmarking regarding organizations' maturity since its fundamental premise is a pairwise comparison between companies to obtain their classification. Based on a literature search to identify the existing maturity models, the CMMI model was selected since it is the most recurrent in the literature on managing organizational Green IT actions. The classification process using CMMI maturity levels as classes is based on the ELECTRE IV multicriteria decision support method, which was developed to work specifically with classification problems. The results include the companies' allocation into the most appropriate classes, considering well-defined criteria set with their weights, the class boundaries according to numerical parameters such as lower and upper limits for each of them, and data collected on companies under consideration for the assessment.

**Keywords:** green information technology; maturity; multicriteria model; class structure; ELECTRE IV; sustainable strategies; assessment; benchmarking

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## 1. Introduction

With the crescent number of discussions about environment conservation, energy consumption, greenhouse gas emissions, and pollution and the emergency of new environmental legislation, Green Information Technology (IT) has emerged as a prominent topic related to using IT resources in an energy-efficient and cost-effective manner [1,2].

In this way, the use of IT moves toward sustainability, which has three fundamental components: economic growth, describing the economic activities that interact and impact social and environmental components in the society; social equity, which corresponds to human rights, corporate power, and environmental politics; and finally environmental protection, pursuing healthy ecosystems that can continuously provide goods and services to human beings and other organisms on earth [3].

According to Bose and Luo [1], the Green IT literature is heavily based on case studies, anecdotes, and surveys of current practices, and there is a gap in terms of theoretic framework proposals that organizations can use for assessing their potential for undertaking to Green IT. Singh and Sharma [4] also refer to a gap in the literature related to the Green IT primary constructs involving green brand image, competitive advantage, and sustainable development, all as competitive advantages for companies.

In this context, assessing Green IT maturity in organizations is essential to understand how their initiatives in adopting sustainable technologies are progressing [5,6]. The main objective of this paper is to propose a Green IT Maturity Class Structure to be applied in assessing the organizational level of sustainable IT strategies, providing a way to develop benchmarking among companies.

## 2. Background

### *2.1. The Green IT Organizational Relevance*

Organizations began to see Green IT as part of their strategy by the need to comply with what is established by environmental regulations that applies to energy consumption, food production, water usage, pollution, waste disposal, environmental awareness, and resource efficiency [7].

There are several motivators for Green IT, such as those identified and discussed by Bansal and Roth [8] in 2000 and reinforced by most recent studies: competitiveness to improve long-term profitability [4]; regulatory/legislative compliance [9]; and ecological responsibility and awareness, since organizations have social obligations and values to be pursued [5]. Economic motivators include reducing IT operating and capital expenses, reducing energy bills, and enhancing the organization's public image [3,10,11].

Companies can also use Green IT as a tool to promote "sustainable awareness" [5] through its potential as a natural fit for environmental and sustainable education with the use of applications such as virtual learning environments, educational games, and simulation programs [12].

### *2.2. Maturity Models*

The use of maturity models in IT-related disciplines to perform measurements and benchmarks has grown, reinforcing their relevance for organizational development [13]. Maturity models are strategic tools developed to assess the maturity of a specific domain based on a comprehensive set of criteria [14], providing a vision of strengths, weaknesses, opportunities, and threats in the organizational environment, allowing the firms to develop strategies to gain competitive advantages [15].

Santos-Neto and Costa [13] conducted a survey covering the period from 1976 to 2017, demonstrating researchers' crescent interest in enterprise maturity models. The observations made by these authors reaffirm the relevance of studies on maturity models and also demonstrate that there is openness to new analyses, applications, and improvements in existing knowledge. Table 1 contains some examples of maturity models.

**Table 1.** Examples of Maturity Models.

| Maturity Model | Description |
|---|---|
| Capability Maturity Model Integrations (CMMI) | A software and systems engineering reference model focusing on developing new software products. |
| Business Process Maturity Model (BPMM) | BPMM is a generic designation for all kinds of maturity models focused on business process management maturity assessment. |
| ISO/IEC 15504—Software Process Improvement and Capability Determination (SPICE) | Based on the prescription of minimum requirements for inputs, outputs, resources, and activities for software engineering processes. |
| Organizational Project Management Maturity Model (OPM3) | Designed to help organizations to assess and improve their project management capabilities. |
| Projects in Controlled Environments 2 Capability Maturity Model (P2CMM) | Based on PRINCE2; focused on the necessary management activities for the process of project management. |

In complement to these models, for the specific case of Green IT, Bose and Luo [1] suggest a series of three stages for implementing it based on the innovation diffusion literature: (i) Pre-adoption Stage, based on the initial use of the Green IT; (ii) Formal Adoption Stage, with the integration of the initiatives; (iii) Post-adoption Stage, with the full-scale deployment when the Green IT becomes an integral part of firm value chain activities, is represented by the initiatives' maturation.

## 3. A Maturity Scale for Green IT in Organizations

Among the five presented maturity models in Table 1, CMMI, created by the Software Engineering Institute of Carnegie Mellon University, is the most widely used by the IT industry, mainly in software engineering processes. According to Patón-Romero et al. [5], the CMMI is the most adopted and enhanced model in all literature studies that they have identified.

The CMMI is scoped towards development, acquisition, and services, called the three constellations, and it describes three capability levels (the Continuous Representation for Capability Levels), five maturity levels (the Staged Representation for Maturity Levels), and a pseudo-level 0 in both cases for organizations that have no standard development process [5,16]. Table 2 presents the maturity levels and their descriptions.

**Table 2.** CMMI Staged Representation for Maturity Levels.

| Level | Description |
|---|---|
| 0—Incomplete | No process is in place; success depends only on personal skills. |
| 1—Initial | Unpredictable processes with poor control and reactivity. |
| 2—Managed | Projects and reactivity characterize processes. |
| 3—Defined | Organization and proactivity characterize processes. |
| 4—Quantitatively Managed | Processes are measured and controlled. |
| 5—Optimized | Focus on process improvement. |

In addition to the maturity levels, there are four categories in which the process areas may be defined: Project and Work Management, Process Management, Support and Services Establishment, and Delivery. The CMMI for Services is aligned with the Green IT proposal in the organizations, as presented in Section 2.1. It was designed based on models and standards related to the governance area such as Information Technology Infrastructure Library (ITIL), ISO/IEC 20,000 Control Objectives for Information and related Technology (CobIT), and Information Technology Services Capability Maturity Model (ITSCMM) [16].

## 4. The Assessment Process Involving the Green IT Maturity Model

The definition of the maturity model, to apply its levels as classes, will occur according to CMMI, as described in the previous section. Figure 1 describes the five major methodological phases for the maturity assessment considered in our research.


**Figure 1.** Methodological phases for the Maturity Assessment.

**Phase 1**, *Maturity Model Definition*, is what we are presenting in this paper: the definition of the maturity model to be applied with a classification process in Phase 2, *Classification Process Definition*. For **Phase 2**, we are considering the multicriteria decision support model ELECTRE (Elimination and Choice Translating Reality) TRI, developed to work specifically with classification (sorting) problems [17].

**Phase 3** represents the *Data Collection and Preparation* task, considering the aspects (or criteria) defined in the previous phases to enable concrete and concise Green IT maturity assessment within organizations. These aspects must be aligned to sustainable IT use in organizations and well described to avoid confusion and ambiguity in the data collection. The data preparation consists of transforming the collected data into a format acceptable for **Phase 4**, *Running the Classification process according to the Maturity Model*. The main objective of moving from Phase 3 to Phase 4 is to keep the model's coherence.

Finally, **Phase 5** consists of the *Results and Scenario Changes Analysis*, considering that the initial organizations' classification can suffer variations according to possible changes in the model's parameters, such as weights, number of criteria, and number of organizations participating in the analysis.

*Classification Scheme and Interpretations*

The ELECTRE TRI classification scheme can be exemplified by Figure 2, where each $C_p$ is a class (or category) that will be defined according to the maturity model adopted.

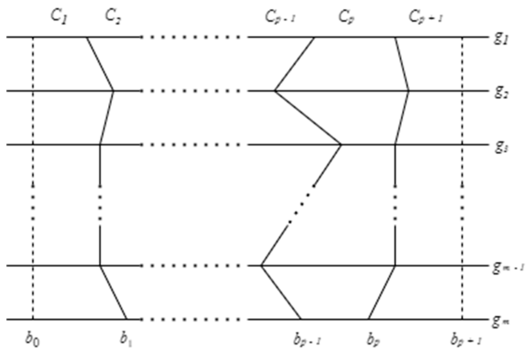


**Figure 2.** Classification scheme, defining the classes (or categories) using limiting profiles.

The results of the classification process can be interpreted according to the outranking relation *S*, which validates or not the association between the alternatives in the analysis. Each category $C_p$ is delimited by lower and upper limits $b_{p-1}$ and $b_p$ regarding their evaluations $g_m(b_{p-1})$ and $g_m(b_p)$ for each criterion considered in the assessment model. There are also three thresholds to be defined for the classifications: veto ($v$), preference ($p$), and indifference ($q$). The results can be presented in both optimistic (or disjunctive) and pessimistic (or conjunctive) procedures according to the ELECTRE-TRI algorithm [18–20].

Emamat et al. [20] presented the ELECTRE-TRI algorithm in five fundamental steps, which are briefly:

*Step 1*—Compute partial concordance indices ($c_j(a,b_h)\ \forall j \in F$);
*Step 2*—Compute the comprehensive concordance index ($c(a,b_h)$);
*Step 3*—Compute discordance indices ($d_j(a,b_h)\ \forall j \in F$);
*Step 4*—Compute the credibility index of the outranking relation ($\sigma(a,b_h)$);
*Step 5*—Assign alternatives to categories using the *Pessimistic* and the *Optimistic* procedures.

*Pessimistic procedure:* compare $a$ to $b_t$, with $t = p, p-1, \ldots, 1$; $b_h$ is the first profile such that $aSb_h$; assign $a$ to category $C_{h+1}$.
*Optimistic procedure:* compare $a$ to $b_t$, with $t = 1, 2, \ldots, p$; $b_h$ is the first profile such that $b_h \succ a$; assign $a$ to category $C_h$.

The maturity model presented in Table 2 supports the pre-definition of the number of classes to be implemented in the classification model: each CMMI level can be defined as a class/category in the classification model, leaving only the definition of mathematical parameters such as the upper and lower limits of each class, and the thresholds, as defined above. The criteria's definition is conceptual, linked to the aspects to be evaluated according to the maturity model.

## 5. Final Considerations

This paper communicates a proposal for applying a maturity model to assess the maturity level of the use of Green IT in organizations. Its application was designed to evaluate several companies at once, providing a form of benchmarking on their sustainable IT strategies so that they can have an overview of this specific component within their general plan of actions and strategies in favor of sustainability and its internal and external effects (in this last case on society).

The continuity of this research involves: (a) the definition of criteria aligned with aspects of sustainable use of IT in organizations, in addition to allowing an assessment based on levels that allow the categorization of companies according to the categories defined through the maturity model; (b) numerical simulations for initial validation of the application of the maturity model in the classification process; (c) selection of a sample of companies for data collection, so that a real benchmarking can be carried out according to their maturity in Green IT.

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