A SPICE-based Maturity Model for the Governance and Management of Green IT

J. David Patón-Romero[1(✉)], Moisés Rodríguez[1,2], and Mario Piattini[1]

[1] Alarcos Research Group, Institute of Technologies and Information Systems, University of Castilla-La Mancha (UCLM), Paseo de la Universidad, 4, 13071 Ciudad Real, Spain
[2] AQCLab, Camino de Moledores, 13051 Ciudad Real, Spain
JoseDavid.Paton@gmail.com, mrodriguez@aqclab.es, Mario.Piattini@uclm.es

Abstract. Organizations around the world are increasingly concerned about the environment, adopting sustainable practices in their business processes. In the field of Information Technologies (IT) several Green IT practices have been proposed, but in isolation, so a framework is needed if the Green IT is to be implemented and improved in an efficient and integrated way. In this paper, we propose a maturity model (based on SPICE) to help organizations to implement the governance and management of Green IT gradually, as well as to improve their maturity level in this area. The validation of this proposal by experts and a case study seems to indicate that the proposal can be useful for implementing and improving the Green IT processes in organizations.

Keywords: SPICE · ISO/IEC 15504 · Maturity Model · Green IT · Governance · Management

1 Introduction

In recent years, Information Technology (IT) has become one of the pillars of our society, changing not only the way we relate to each other and the way companies do business, but also how we interact with the planet. However, in this interaction with the planet we have lost our commitment to the environment, our commitment to life. Therefore, in our society a strong ecological awareness has emerged in order to address this problem, with the aim of obtaining a healthy planet and a sustainable ecosystem.

That is why in the area of IT has emerged the concept of Green IT, which seeks to bring the idea of environmental sustainability [1] closer to IT. Green IT can be defined as "*the study and practice of design, manufacture and use of hardware, software and communication systems with a positive impact on the environment*" (definition adapted from [2]).

The importance of the idea of sustainability in our society and the growing demand of "green" products has made Green IT a determining area, gaining increasing importance within organizations, since it has become an important asset to add value to the business.

However, while there is a growing number of research papers and isolated best practices of Green IT, there are still no specific standards to help organizations to establish the bases of these best practices (the governance and management of Green IT) and to verify that these Green IT implementations are sufficient, correct and work as expected [3].

That is why we have developed a first version of the "Governance and Management Framework for Green IT" [4], in which we have established the necessary characteristics to define, implement and audit the governance and management of Green IT in an organization. This developed framework however lacks a maturity model through which the characteristics of governance and management of Green IT established in this framework can be gradually evaluated and implemented.

Thus, in this paper we propose a maturity model based on SPICE (a process reference model) for the governance and management of Green IT, i.e., a SPICE-based maturity model for the "Governance and Management Framework for Green IT".

The rest of this paper is organized as follows: Section 2 explains the related work about the existing maturity models that are related to the subject of study (SPICE, IT, Green and Green IT); Section 3 presents the proposal of the SPICE-based maturity model for the "Governance and Management Framework for Green IT"; Section 4 shows the validations carried out for the process reference model proposed; and, finally, Section 5 presents the conclusions and future work to be done in this area. Also, Appendix A shows the definitions and purposes of the processes of the "Governance and Management Framework for Green IT" organized according to the proposed SPICE maturity levels.

2 Related Work

In the following sub-sections, the different maturity models based on SPICE and related to the area of IT, sustainability (Green) and Green IT are analyzed.

2.1 SPICE-based Maturity Models

The ISO/IEC 15504 [5], also known as Software Process Improvement Capability Determination (SPICE), is a set of standards, developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), that propose models for the improving and assessing of processes related to information systems and software products.

SPICE has been applied in many fields such as aerospace [6], software engineering [7], government [8], risk management [9], automotive [10, 11], information security [12], health [13, 14], nuclear energy [15], among others. However, so far there is no application of this standard in the field of Green IT.

It is also important to note that a few years ago (in 2012 at the ISO/IEC JTC 1/SC 7 plenary meeting in Jeju, South Korea) a proposal for defining an extension to the ISO/IEC 15504 to embrace sustainability was presented and accepted but failed to obtain enough resources to be carried on. It was a shame because we believe that it was a missed opportunity to advance in this area.

2.2 Other IT Maturity Models

In relation to the others maturity models related to the area of IT, the most ingrained and widely-used today by organizations are outlined below:

- ISO/IEC 33000 [16]: this new family of standards, developed by ISO and IEC, is replacing ISO/IEC 15504, reorganizing and extending the latter for the evaluation and improvement of the capacity and maturity of an organization's processes. Based on these family of standards, we developed a model for data quality processes implantation [17].
- Capability Maturity Model Integration (CMMI) [18]: this model, originally developed by Carnegie Mellon University (CMU) and administered nowadays by the CMMI Institute (acquired recently by ISACA - *Information Systems Audit and Control Association*), aims to evaluate and improve the processes of an organization for the development, maintenance and operation of information systems and software products.
- Maximizing the Combined Effects of COBIT 5 and CMMI [19]: this proposal is being developed by ISACA, in order to adapt the CMMI model to COBIT 5 (*Control Objectives for Information and related Technology*) [20], identifying at which maturity levels of the CMMI model must the different COBIT 5 processes of governance and management of IT be included.

2.3 Green and Green IT Maturity Models

In [21] a systematic mapping study is carried out in relation to the sustainability maturity models that currently exist, placing special emphasis on the area of Green IT. The study demonstrates the limited number of studies related to maturity models of sustainability (only 26 studies have been found) and, in particular, of Green IT (only 8 studies in this field).

This systematic mapping study also shows the need to validate the maturity models proposed by the studies, since only 8 of the studies found validate their proposal. And, in particular, in relation to the proposed Green IT maturity models, only 2 are validated: study [22] carries out a validation through a case study, and study [23] through a survey.

It is important to highlight that, in addition to the Green IT maturity models found in this systematic mapping study, we have found as gray literature another study [24] that proposes a Green IT maturity model based on CMMI, validated through a case study.

On the other hand, in the results of the systematic mapping study we can observe that there are no sustainability models or Green IT models that follow ISO/IEC 15504 (SPICE), which demonstrates the importance of exploiting this area of SPICE-based maturity models of sustainability.

Therefore, the results of this systematic mapping study demonstrate the youth of this area of maturity models related to sustainability. Also, in relation to Green IT, it is not only important to develop common and updated frameworks, but also maturity models for these frameworks that allow the gradual implementation, evaluation and improvement of Green IT practices carried out by organizations.

3 SPICE-based Maturity Model for the "Governance and Management Framework for Green IT"

The great growth of the idea of sustainability and, in particular, Green IT within organizations has led to the emergence of more and more research papers and isolated best practices in this respect.

That is why, in the absence of a framework or standard to carry out these Green IT practices, we have developed a first proposal of the "Governance and Management Framework for Green IT" [4] (GMGIT, hereinafter), based on the structure of enablers of the COBIT 5 framework [20], which aims to optimize and standardize the adoption of Green IT in organizations.

However, this first version of the GMGIT lacks a maturity model that allows organizations to gradually implement, evaluate and improve their maturity level in the area of governance and management of Green IT.

For this reason, in this paper we propose a maturity model (a process reference model) for the "Governance and Management Framework for Green IT", based on the default standard to evaluate and improve the maturity level in IT, ISO/IEC 15504 (SPICE).

The application of the different characteristics of the SPICE standard to the "Governance and Management Framework for Green IT" is shown below.

First, SPICE establishes 6 maturity levels, which we have adapted to the area of Green IT as follows:

- **Level 0 (Incomplete).** The organization does not take sustainability into account, and no Green IT practice is defined.
- **Level 1 (Performed).** The organization takes sustainability into account, and carries out Green IT practices in the most critical aspects related to sustainability.
- **Level 2 (Managed).** The Green IT practices are clearly defined, established and managed throughout the different business areas, contributing to sustainability in and by IT.
- **Level 3 (Established).** The organization follows the recognized standards and best practices of Green IT (Green IT is correctly managed and governed), as well as identifies in a continuous way and ensures the compliance with the external requirements.
- **Level 4 (Predictable).** The organization carries out the monitoring, evaluation and measurement of implemented Green IT practices, through a set of sustainability metrics established for that purpose.
- **Level 5 (Optimizing).** The organization is fully committed to sustainability and is oriented towards the continuous improvement of implemented Green IT practices, by means such as for example detailed performance reports, exhaustive use of sustainability metrics, and management of the innovation process in sustainability.

Second, in each of these maturity levels of Green IT, the different processes of the GMGIT have encompassed, as shown in the Table 1. It is important to note that the GMGIT does not include all the processes defined by COBIT 5, but of the 37 processes

of COBIT 5 we select and adapt to Green IT 15 of them, which we consider most directly related to this area.

Table 1. SPICE maturity levels of the processes of the "Governance and Management Framework for Green IT".

Process	Level 1	Level 2	Level 3	Level 4	Level 5
EDM01: Ensure governance framework setting and maintenance			X		
EDM02: Ensure benefits delivery			X		
EDM03: Ensure risk optimization					X
EDM04: Ensure resource optimization					X
EDM05: Ensure stakeholder transparency			X		
APO01: Manage the IT management framework		X			
APO02: Manage strategy		X			
APO06: Manage budget and costs		X			
APO08: Manage relationships		X			
BAI02: Manage requirements definition		X			
BAI03: Manage solutions identification and build		X			
BAI09: Manage assets	X				
DSS01: Manage operations	X				
MEA01: Monitor, evaluate and assess performance and conformance				X	
MEA03: Monitor, evaluate and assess compliance with external requirements			X		

Finally, we have described each of the GMGIT processes according to the SPICE standard, i.e., identifying the attributes of each process, through which the compliance with said process can be analyzed. Table 2 shows by way of example the SPICE-based description of one of the GMGIT processes.

Table 2. SPICE-based description of the process "DSS01: Manage operations".

Attribute	Description
Process ID	DSS01
Process Name	Manage operations.
Process Description	Co-ordinate and execute the activities and operational procedures required to deliver internal and outsourced IT services, including the execution of pre-defined standard operating procedures and the required monitoring activities.
Process Purpose	Deliver IT operational service outcomes as planned.

<table>
<tr><th>Attribute</th><th>Description</th></tr>
<tr><td>Process Outcomes</td><td>As a result of successful implementation of “Manage operations”:
1. The operations of Green IT are carried out following the policies, principles, strategy and goals of Green IT.
2. The standards, regulations and best practices of Green IT have been identified and implemented and are being complied with.</td></tr>
<tr><td>Best Practices</td><td>DSS01.BP1: Perform operational procedures. Maintain and perform operational procedures and operational tasks of Green IT reliably and consistently. [Outcome: 1]
DSS01.BP2: Manage outsourced services. Manage the operation of outsourced services so as to maintain their reliability and their consistency with the organization’s Green IT. [Outcome: 1]
DSS01.BP3: Monitor IT infrastructure. Monitor the IT infrastructure and events related to it, in an effort to ensure the alignment of all of them with the organization’s Green IT. Store sufficient chronological information in operations logs to enable the reconstruction, review and examination of the time sequences of operations and the other activities surrounding or supporting those operations. [Outcome: 2]
DSS01.BP4: Manage the environment. Maintain measures for protection against environmental factors. Install specialized equipment and devices to monitor and control the environment from the point of view of Green IT. [Outcome: 2]
DSS01.BP5: Manage facilities. Manage facilities in line with laws, regulations, guidelines and other requirements related to Green IT. [Outcome: 2]</td></tr>
<tr><td>Work Products</td><td>
<table>
<tr><th>Inputs</th><th>Outputs</th></tr>
<tr><td>Policies of Green IT. [Outcome: 1]</td><td>Operational procedures of Green IT. [Outcome: 1]</td></tr>
<tr><td>Policies of management of the environment. [Outcome: 2]</td><td>Reports on the compliance of Green IT by third parties. [Outcome: 1]</td></tr>
<tr><td>Policies of management of the facilities. [Outcome: 2]</td><td>Reports on the performance of the infrastructure of the IT, from the point of view of Green IT. [Outcome: 2]</td></tr>
<tr><td></td><td>Alignment of Green IT with the management of the environment. [Outcome: 2]</td></tr>
<tr><td></td><td>Alignment of Green IT with the management of the facilities. [Outcome: 2]</td></tr>
</table>
</td></tr>
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4 Validations

To verify the consistency and applicability of the SPICE-based maturity model for the GMGIT proposed in the previous section, we have carried out a couple of validations through a workshop with experts and through a case study in an IT service center.

4.1 Workshop

First of all, we decided to hold a workshop with experts in order to obtain a validation from a theoretical point of view, refining the proposed model before moving on to the practical level. These experts, five in all, belong to an IT department, have more than 10 years of experience in research and IT audits (with certification in CISA - *Certified Information Systems Auditor*), and are currently working on issues related to Green IT, IT, auditing and maturity models.

During the workshop, the GMGIT and the SPICE maturity levels adapted to Green IT were presented and discussed first. Following this, each of the experts was asked for his proposal about at what maturity level should be found each of the processes defined in the GMGIT and each of these proposals was discussed.

After discussing the proposals of the experts and reaching a general proposal, we presented our proposal of the SPICE maturity levels of each of the GMGIT processes. Both proposals were discussed and the final proposal of the SPICE-based maturity model for the GMGIT was reached.

4.2 Application in a IT Services Center

In second place, we carried out a case study in a IT service center (for reasons of confidentiality identified hereinafter as SC), which is responsible for the management of IT services of a university of more than 30,000 students and is distributed in several campuses. Currently, the SC is beginning to implement sustainable measures in different areas of the business, including the following Green IT measures:

- Implementation of cloud computing services.
- Establishment of a corporate printing service, reducing the number of printing devices and raising awareness of the need to save ink and paper.
- Implementation of a service of withdrawal and recycling of electrical and electronic waste.
- Acquisition of IT equipment according to internationally recognized sustainability standards such as UE Energy Star v5, ISO 14001 o ISO 779/9296.
- Redesign of the data center, to improve energy efficiency and cooling.

Thanks to these Green IT measures, the SC has achieved good results in favor of environmental sustainability:

- Reduction of 20% of the energy destined for the cooling of the data center (obtaining a PUE - *Power Usage Effectiveness* of 1.4).
- Reduction of 52% of CO_2 emissions from university IT.
- Withdrawal of more than 48 tons of obsolete computer equipment for recycling.

From these results, it is estimated that the university has avoided the generation of 7,261kg of CO_2 and has produced a saving of 2,631m^3 of water.

However, these Green IT practices have been carried out in an isolated manner and without following a specific framework or standard. For this reason, the SC decided to carry out an audit following the GMGIT, in order to know its current state of Green IT and adopt the framework to implement, evaluate and improve the Green IT.

In this audit, the high involvement of the SC with sustainability was observed, but many shortcomings were identified, especially in the definition and formalization of the Green IT practices.

Analyzing these results and applying them to the developed SPICE-based maturity model, we have concluded that the SC is partially at Level 1, as can be seen in Table 3.

Table 3. Fulfillment of the processes and their best practices of Level 1 in the SC.

Processes and their Best Practices of Level 1	Yes	Partially	No
BAI09: Manage assets			**X**
BAI09.BP1: Identify and record current assets			X
BAI09.BP2: Manage critical assets			X
BAI09.BP3: Manage the asset life cycle			X
BAI09.BP4: Optimize asset costs			X
BAI09.BP5: Manage licenses			X
DSS01: Manage operations		**X**	
DSS01.BP1: Perform operational procedures		X	
DSS01.BP2: Manage outsourced services	X		
DSS01.BP3: Monitor IT infrastructure	X		
DSS01.BP4: Manage the environment			X
DSS01.BP5: Manage facilities	X		

We are currently working with the SC to overcome the deficiencies found, in order to reach the Level 1 of maturity of Green IT and start to work on the following levels, gradually implementing the Green IT and improving its maturity level in this area.

5 Conclusions and Future Work

Organizations, in their quest to improve and gain more and more value, have realized the enormous potential and impact of the idea of sustainability within their models and areas of the business. That is why the organizations are increasingly rethinking their way of interacting with the environment and have begun to act in this regard in the area of IT, implementing Green IT initiatives in their processes and daily operations.

However, in this area of the Green IT organizations do not have any specific standards or frameworks to help them to implement, evaluate and improve the Green IT practices that they carry out.

In order to overcome this obstacle, we have developed the "Governance and Management Framework for Green IT" and, in the present paper, we propose a SPICE-based maturity model for this framework, thanks to which it is intended to help to gradually implement new practices of Green IT in an organization, as well as to evaluate and improve the maturity level of Green IT of an organization.

In the first validations of the proposed maturity model carried out, we have managed to consolidate at theoretical and practical level the utility of this model for organizations in this area of Green IT.

However, this is only a starting point and we will continue working in this area of Green IT, developing and improving through more validations both the "Governance and Management Framework for Green IT" and the maturity model proposed in this paper, making them into standards-compatible models.

On the other hand, we also intend to bring the ISO 14000 family of standards [25] closer to Green IT, in order to identify those characteristics that can be integrated into the "Governance and Management Framework for Green IT", serving as a guide for those organizations that seek a certification in this standard.

Sustainability is a reality in all areas of knowledge and a fundamental aspect for life, so it is our duty to defend this idea, to protect the environment, and work towards a better and more sustainable future.

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Appendix A: Processes of the "Governance and Management Framework for Green IT" organized by the SPICE Maturity Levels

A.1 Level 1

BAI09: Manage assets

- **Description of the process:** Manage IT assets through their life cycle to make sure that their use delivers value at optimal cost, they remain operational (fit for purpose), they are accounted for and physically protected, and those assets that are critical to support service capability are reliable and available. Manage software licenses to ensure that the optimal number are acquired, retained and deployed in relation to required business usage, and the software installed is in compliance with license agreements.
- **Statement of the purpose of the process:** Account for all IT assets and optimize the value provided by these assets.

DSS01: Manage operations

- **Description of the process:** Co-ordinate and execute the activities and operational procedures required to deliver internal and outsourced IT services, including the execution of pre-defined standard operating procedures and the required monitoring activities.
- **Statement of the purpose of the process:** Deliver IT operational service outcomes as planned.

A.2 Level 2

APO01: Manage the IT management framework

- **Description of the process:** Clarify and maintain the governance of organization IT mission and vision. Implement and maintain mechanisms and authorities to manage information and the use of the organization IT in support of governance objectives in line with guiding principles and policies.
- **Statement of the purpose of the process:** Provide a consistent management approach to enable the organization governance requirements to be met, covering management processes, organizational structures, roles and responsibilities, reliable and repeatable activities, and skills and competencies.

APO02: Manage strategy

- **Description of the process:** Provide a holistic view of the current business and IT context, the future direction, and the initiatives required to migrate to the desired future context. Leverage organization architecture building blocks and components, including externally provided services and related capabilities to enable nimble, reliable and efficient response to strategic objectives.

- **Statement of the purpose of the process:** Align strategic IT plans with business objectives. Clearly communicate the objectives and associated accountabilities so they are understood by all, with the IT strategic options identified, structured and integrated with the business plans.

APO06: Manage budget and costs

- **Description of the process:** Manage the IT-related financial activities in both the business and IT functions, covering budget, cost and benefit management, and prioritization of spending through the use of formal budgeting practices and a fair and equitable system of allocating costs to the organization. Consult stakeholders to identify and control the total costs and benefits within the context of the IT strategic and tactical plans, and initiate corrective action where needed.
- **Statement of the purpose of the process:** Foster partnership between IT and organization stakeholders to enable the effective and efficient use of IT-related resources and provide transparency and accountability of the cost and business value of solutions and services. Enable the organization to make informed decisions regarding the use of IT solutions and services.

APO08: Manage relationships

- **Description of the process:** Manage the relationship between the business and IT in a formalized and transparent way that ensures a focus on achieving a common and shared goal of successful organization outcomes in support of strategic goals and within the constraint of budgets and risk tolerance. Base the relationship on mutual trust, using open and understandable terms and common language and a willingness to take ownership and accountability for key decisions.
- **Statement of the purpose of the process:** Create improved outcomes, increased confidence, trust in IT and effective use of resources.

BAI02: Manage requirements definition

- **Description of the process:** Identify solutions and analyze requirements before acquisition or creation to ensure that they are in line with organization strategic requirements covering business processes, applications, information/data, infrastructure and services. Co-ordinate with affected stakeholders the review of feasible options including relative costs and benefits, risk analysis, and approval of requirements and proposed solutions.
- **Statement of the purpose of the process:** Create feasible optimal solutions that meet organization needs while minimizing risk.

BAI03: Manage solutions identification and build

- **Description of the process:** Establish and maintain identified solutions in line with organization requirements covering design, development, procurement/sourcing and partnering with suppliers/vendors. Manage configuration, test preparation, testing, requirements management and maintenance of business processes, applications, information/data, infrastructure and services.

- **Statement of the purpose of the process:** Establish timely and cost-effective solutions capable of supporting organization strategic and operational objectives.

A.3 Level 3

EDM01: Ensure governance framework setting and maintenance

- **Description of the process:** Analyze and articulate the requirements for the IT governance of the organization, and put in place and maintain effective enabling structures, principles, processes and practices, with clarity of responsibilities and authority to achieve the organization's mission, goals and objectives.
- **Statement of the purpose of the process:** Provide a consistent approach integrated and aligned with the organization governance approach. To ensure that IT-related decisions are made in line with the organization's strategies and objectives, ensure that IT-related processes are overseen effectively and transparently, compliance with legal and regulatory requirements is confirmed, and the governance requirements for board members are met.

EDM02: Ensure benefits delivery

- **Description of the process:** Optimize the value contribution to the business from the business processes, IT services and IT assets resulting from investments made by IT at acceptable costs.
- **Statement of the purpose of the process:** Secure optimal value from IT-enabled initiatives, services and assets; cost-efficient delivery of solutions and services; and a reliable and accurate picture of costs and likely benefits so that business needs are supported effectively and efficiently.

EDM05: Ensure stakeholder transparency

- **Description of the process:** Ensure that organization IT performance and conformance measurement and reporting are transparent, with stakeholders approving the goals and metrics and the necessary remedial actions.
- **Statement of the purpose of the process:** Make sure that the communication to stakeholders is effective and timely and the basis for reporting is established to increase performance, identify areas for improvement, and confirm that IT-related objectives and strategies are in line with the strategy of the organization.

MEA03: Monitor, evaluate and assess compliance with external requirements

- **Description of the process:** Evaluate that IT processes and IT-supported business processes are compliant with laws, regulations and contractual requirements. Obtain assurance that the requirements have been identified and complied with, and integrate IT compliance with overall organization compliance.
- **Statement of the purpose of the process:** Ensure that the organization is compliant with all applicable external requirements.

A.4 Level 4

MEA01: Monitor, evaluate and assess performance and conformance

- **Description of the process:** Collect, validate and evaluate business, IT and process goals and metrics. Monitor that processes are performing against agreed-on performance and conformance goals and metrics and provide reporting that is systematic and timely.
- **Statement of the purpose of the process:** Provide transparency of performance and conformance and drive achievement of goals.

A.5 Level 5

EDM03: Ensure risk optimization

- **Description of the process:** Ensure that the organization's risk appetite and tolerance are understood, articulated and communicated, and that risk to organization value related to the use of IT is identified and managed.
- **Statement of the purpose of the process:** Ensure that IT-related organization risk does not exceed risk appetite and risk tolerance, the impact of IT risk to organization value is identified and managed, and the potential for compliance failures is minimized.

EDM04: Ensure resource optimization

- **Description of the process:** Ensure that adequate and sufficient IT-related capabilities (people, process and technology) are available to support organization objectives effectively at optimal cost.
- **Statement of the purpose of the process:** Ensure that the resource needs of the organization are met in the optimal manner, IT costs are optimized, and there is an increased likelihood of benefit realization and readiness for future change.