REVIEW ARTICLE

# Approaching Green BPM characterisation

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## Abstract

Sustainable development is a type of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability has recently become more and more important for businesses. This has led to what is known as Green BPM (Green business process management), in which sustainability is considered to be a business objective. The objective of this work was to carry out a systematic literature review in order to evaluate how the subject of Green BPM has evolved and how the term "Green BPM" has been conceptualised so as to propose a new definition compiled from those previously formulated; identify the impact of the incorporation of Green aspects into the BPM life cycle stages; and discover the impact of Green BPM research efforts by means of the PDCA (plan-do-check-act) model, thus identifying (1) the goals that have been proposed when Green initiatives are carried out in BPM, (2) the context in which this has been applied, and (3) the performance indicators considered. Finally, we propose a new characteristic, Process Greenability, together with its subcharacteristics, in addition to identifying the relationship between these subcharacteristics and the indicators identified to make them measurable.

### KEYWORDS

BPM, Green BPM, Green business process management, SLR, systematic literature review

## 1 | INTRODUCTION

A present-day sustainable company must not only measure indicators of its impact on economic, social, and human dimensions but also attempt to minimise its impact on the environment.

In 2015, a manifesto containing a set of principles and commitments linked to sustainable design appeared.[1] Its authors stated that, in addition to being multidimensional, sustainability is systematic, is never an isolated property, and should be applied to the system and context of which it is a part. They also noted that ensuring sustainability requires long-term planning and taking action at multiple levels.

Furthermore, if companies wish to commit to sustainability, Barbian[2] proposes that they must follow five descriptors: (1) focus primarily on their employees and customers, (2) work to conserve nature, (3) consider that equality and justice are important in all spheres, (4) view the enterprise as a whole, in which each part is important, and (5) commit to the production of long-lasting hard-wearing products.

For a company to be "sustainable," it must consider aspects such as the carbon footprint, the consumption of renewable energy, the production of waste, and other indicators of environmental performance.[3]

It is, therefore, necessary to broaden our view of business process management towards the notion of "Green BPM (Green business process management)," which incorporates sustainability as an objective and as a vehicle for the management of changes to business processes and which must be adapted to the changes implied in integrating sustainability into businesses.

In the last few years, the concept of Green BPM has been reviewed in various systematic literature reviews (SLRs).[4-7] SLRs make it possible to obtain new findings and to propose innovative ideas for future research. The planning and methodical systematic execution of the review of primary studies provide the conclusions of the SLR with a higher level of validity than that which could be obtained by analysing the individual

studies and make it possible to compile empirical evidence published in a given period and regarding a specific subject.[8,9] The aforementioned SLRs on Green BPM have focused specifically on the following:

- the evaluation of Green IS (information systems), Green IT (information technology), BPM, and Green BPM so as to identify the actions that an organisation should take in order to become sustainable and Green,
- the relationship between information systems and BPM, and
- the identification of the aspects on which future works in the field must focus. However, none of them have appropriately characterised Green BPM. An appropriate characterisation of Green BPM would contribute towards enabling organisations to become Green and sustainable.

Some of the aspects that could contribute to the characterisation of Green BPM could be as follows:

- the existence or nonexistence of a consensus as to the meaning of the term "Green BPM";
- the changes in the design, monitoring, operation of, and improvement to the management of business processes in order to make them Green; and
- the definition of environmental performance indicators (EPIs) or key environmental indicators (KEIs) that will make it possible to evaluate the environmental sustainability of business processes.

The objective of this work is to carry out a systematic literature review with the aim of answering these and other questions related to the characterisation of Green BPM. Section 2 provides a generic description of the concepts of BPM and Green BPM so as to then be able to show information regarding the systematic literature review carried out. This begins with the study design (Section 3), which is followed by the study plan (Section 4) and the execution (Section 5). The results obtained from the SLR are shown in Section 6. Other findings regarding Green BPM that are not directly related to our research questions, but that have arisen during the analysis of the works obtained, are discussed in Section 7. The limitations of our study and the threats to its validity are shown in Section 8, and our conclusions are presented in Section 9.

## 2 | BPM AND GREEN BPM

Bearing the context of this work in mind, in this section, we introduce certain definitions and characteristics related to BPM, along with those specifically related to Green BPM. BPM (business process management) refers to a disciplined approach that is employed to identify, design, execute, document, measure, monitor, and control automated and nonautomated business processes in order to achieve coherent results aligned with an organisation's strategic objectives.[10] These include the methods, techniques, and tools required to support the design, promulgation, management, and analysis of operative business processes.[11]

Business process management supports the life cycle of business processes through the participation of the various parties that cooperate with each other in order to attain common business objectives. These activities include the definition, execution, follow-up, control, and analysis of business processes, in addition to their improvement.[12] Although BPM is a well-defined and accepted concept, this is not the case with Green BPM, and it is possible to find various definitions of and approximations to this concept:

- Green BPM describes a new technology that extends BPM (the design, analysis, execution, and monitoring processes) in order to take into account the impact of the carbon footprint.[13]
- Any business process requires consumables from the environment that are then transformed into products, and the sustainability of a product can be defined in terms of renewable and nonrenewable consumables and of the outputs resulting from this process.[14]
- While conventional business process management is focused on the optimisation of costs, quality, time, and the flexibility of the business processes, Green business process management additionally considers the environment and the balance among all of the perspectives.[15]
- For a business to be sustainable, the processes and practices must be carried out in accordance with the principles of corporate sustainability and by actively managing the risks, since they may have a closer relationship with environmental performance. Companies need to promote sustainable products and services, show sustainable development, and contribute towards it.[16] There are other definitions of Green BPM, which will be described in greater detail later in this paper as part of the SLR that we have carried out.

Although all of these definitions are, in general, similar, there is no consensus as to the concept of Green BPM. This is possibly owing to the fact that this concept is so new, and it is, therefore, necessary to compile all these proposals in order to attain a single definition that can be used and understood when we refer to Green BPM.

This is one of the aspects that we shall attempt to deal with and respond to by means of the systematic literature review carried out.

## 3 | STUDY DESIGN

When carrying out a systematic literature review, it is necessary to employ a more rigorous and well-defined approach to review the literature in a specific subject area than when carrying out a traditional literature review. This process takes place in three stages: planning, execution, and reporting (Figure 1, adapted from Genero et al[8]):

- Planning guarantees that the good result expected from an SLR will be obtained, signifying that the research needs, research questions, search strategy, the criteria regarding which works to include and exclude, the strategy employed to evaluate the studies, and the data-selection strategy must be clear.
- The execution consists of carrying out the planned tasks.
- The final stage comprises analysing the primary studies in order to attain conclusions. It is at this moment that the corresponding documentation is created, and the limitations of the study and future work are identified.

Three roles took part in this SLR: the researchers (third and fourth authors), the principal researcher (main author), and the expert reviewer (second author). The workflow followed is shown in Figure 2. The planning stage was the responsibility of the principal researcher, while all three roles participated in the execution. The report of the review was created by the principal researcher and the expert reviewer. In the particular case of the execution, the search strategy was applied by the principal researcher. The construction of the metadata and the initial application of the exclusion criteria were the responsibility of the researchers.

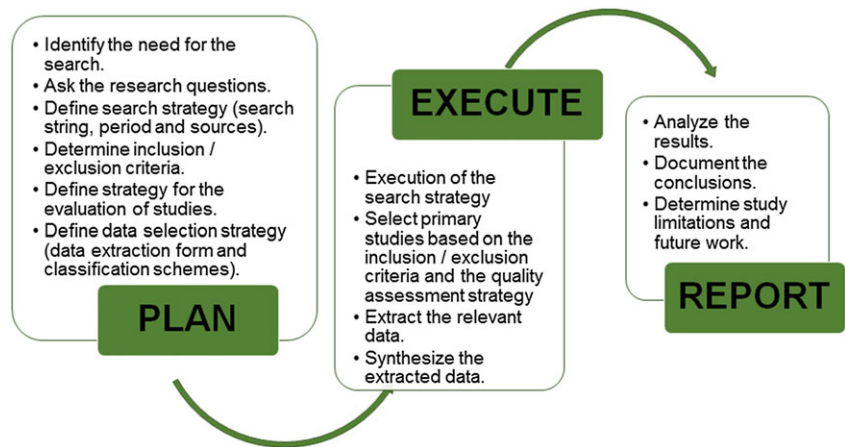The stages of the SLR will be described and detailed in the following sections.



**FIGURE 1**  Steps in a systematic literature review
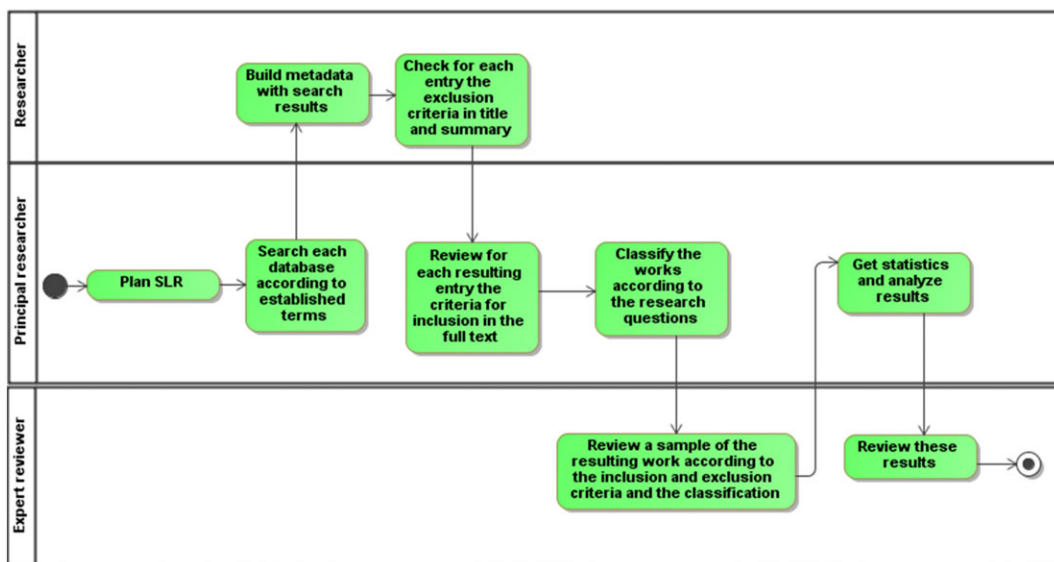


**FIGURE 2**  Work selection workflow

# 4 | SLR PLAN

The first step in an SLR is to plan it. This section shows the tasks involved in order to obtain the review protocol in accordance with the steps defined in Figure 1.

## 4.1 | Need for research

We carried out a classical literature review to discover the current strategy of the research in this field, as a result of which we obtained several works that are commented on below.

The SLR carried out in Stolze et al[4] focuses on whether business process management tools and methods help enterprises to make their business activities more ecological. The term "Green BPM" does not, however, explicitly appear. The authors classify the works in accordance with the subjects that they tackle: Green IT, Green IS, business process, BPM, sustainable, and sustainability. The 108 works associated with BPM and sustainability are subdivided into those that have a clear approach as regards the combination of both terms (8), show some kind of connection between Green IT and/or BPM (34), and mention only sustainability, Green IT, and/or BPM (59), although they do not provide details on the specific contributions that these studies make. They also evaluate the development of standards as extensions of modelling languages used in business process management, concluding that this is an open line of research. Opitz et al[5] present a classification of 27 studies found as Green IS, BPM, and Green BPM. They identify three dimensions for Green BPM: management activities, the stages of the process, and the goals of Green BPM (Figure 3, taken from Opitz et al[5]). The authors reach the conclusion that the majority of the research has focused on the monitoring and measurement stage with the goal of detecting or reducing emissions. Their future work identifies the need to focus on the dimensions proposed and their interrelations. These authors also propose a definition of Green BPM from the point of view of information systems, which would be based both on the works of Seidel et al[3] and Ghose et al[17] and those studies in which Green IS, Green IT, and a company's sustainability are explored in great depth.

In a second review in the same year, the same authors researched what skills an organisation need in order to establish sustainable Green process management and how it might be possible to measure its capacity to do so.[7] The publications were classified according to the aptitude of the company and its employees as regards sustainability; the definition of an ecological strategy that connects the company's business strategy in order to establish an agenda for the Green BPM life cycle; governance using an existing model that organises and manages the actions defined in the strategy; the existence of an ecological model that considers the environmental impact during process modelling; and the Green monitoring of the key dynamic aesthetic indicators of ecological performance for each process in the business process and the possibility of analysing and evaluating the processes after modelling in order to facilitate their Green optimisation with regard to their impact on the environment. They present an adaptation of the Green readiness model containing the Green BPM factors and the modifications to the life cycle, to which they add the classes employed in the classification.

The review presented in Morioka and de Carvalho[16] classifies the publications according to the sustainability performance approaches dealt with (measurement, management, and the presentation of reports), in addition to the dimensions of the term (social, economic, and environmental) and their possible combinations. They propose a reference framework containing the principles and factors that influence sustainable business elements, the corporate sustainability principles that promote collective values in order to promote decision-making, the factors regarding the internal and external context, sustainable business elements (processes and practices, the company's capacity to adapt, the provision of products



Design: representation and modelling of the organizations process
Monitoring: monitoring to produce statistic regarding the performance of he processes
Improvement: change in the organization, the processes and the systems
Implementation: composition and orchestration of the business activities
Operation: execution of the processes

**Plan:** definition of goals and methods with witch to attain them
**Do:** execution of tasks and data collection
**Check:** evaluation the results of the task
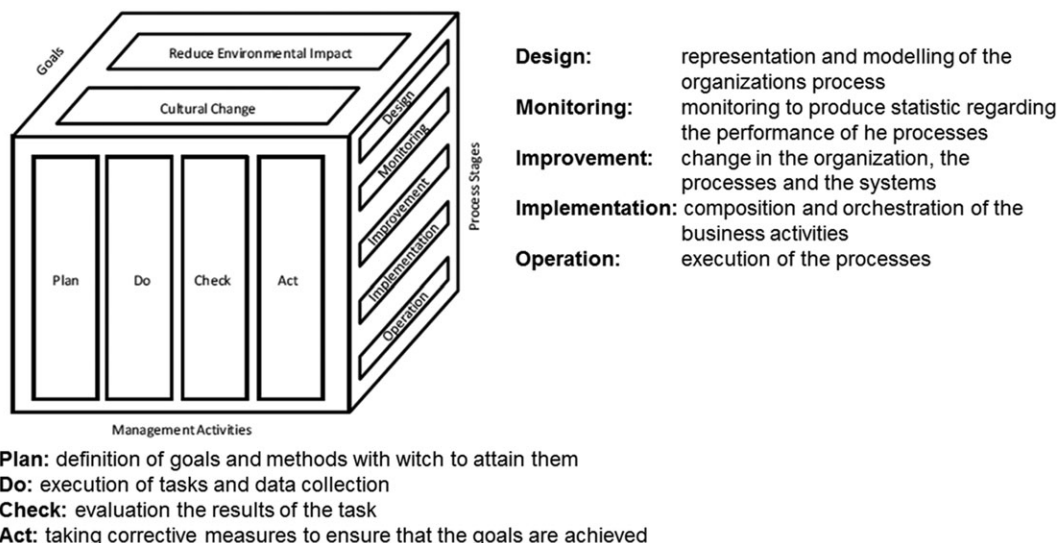**Act:** taking corrective measures to ensure that the goals are achieved

**FIGURE 3** Dimensions in Green BPM research (taken from Opitz et al[5])

and services that reduce the load on the environment, and reports that make it possible to observe the company's contribution to sustainable development).

We also found various works that propose a set of indicators with which to measure environmental sustainability that can be used to evaluate a company's business process operations.[18-21] However, none of them indicate how these categorisations have been considered in the studies on Green BPM.

The questions answered by the SLRs described are summarised in Table 1. We have homogenised the questions (columns 2 to 4) because it was not possible to formulate them in exactly the same way as they appear on the papers. As can be appreciated, none of the works reviewed covers the three questions shown in Table 1, which are, in fact, addressed in our work corresponding to research questions 1, 2, and 7 (see Section 4.2).

Moreover, none of the SLRs studied deals with the Green BPM process, which is also part of our findings and contributions included in this paper.

Finally, although the results obtained in the reviews commented on above are of value as regards exploring the field of Green BPM, none of them has the specific goal of characterising it. A further contribution of our work is, therefore, to provide a response to the lack of Green BPM characterisation so as to encourage its adoption by organisations.

## 4.2 | Research questions

Having identified the need to carry out an SLR, the second step of the planning process consisted of defining questions that would orient the entire review process. Our research objectives and the results obtained from the initial review described above were used as a basis on which to define the following research questions:

RQ1    How have the published works associated with Green BPM evolved?
RQ2    How has Green BPM been defined in literature?
RQ3    Which stages of the process life cycle are involved?
RQ4    Which management activities are involved?
RQ5    Which Green BPM goals are addressed?
RQ6    In what contexts does Green BPM apply?
RQ7    Which environmental performance indicators (EPIs) or key environmental indicators (KEIs) are considered?

**TABLE 1**    Research questions in the SLRs reviewed

| SLR | How Have the Published Works Associated with Green BPM Evolved? | How Has Green BPM Been Defined in Literature? | Which EPIs or KEIs Are Considered? | Other Research Questions in the SLR |
|---|---|---|---|---|
| Stolze et al[4] | X | | | How strongly is the topic of sustainability reflected in the current BPM research literature? |
| Opitz et al[5] | | X | | Which fields of action exist and how can research gaps be closed? |
| Opitz et al[7] | | | | What abilities does an organisation need in order to set up sustainable/green business process management, and how can its capability to do so be measured? |
| Morioka and de Carvalho[16] | X | | | How do the contributions made by the literature on sustainability performance measurement, management and reporting interrelate with each other? How can sustainability performance be integrated into a business in order for it to begin to make improvements to its corporate sustainability? |
| Gohar and Indulska[6] | X | | X | How has BPM research contributed to environmental sustainability (ES)? What BPM concepts have been applied in ES research? What BPM related research gaps are evident, based on ES industry needs? |
| Our proposal | X | X | X | Which stages of the process life cycle are involved? Which management activities are involved? Which Green BPM goals are addressed? In which contexts does Green BPM apply? |

The motivations behind these questions are linked to discovering how the subject of Green BPM has evolved (RQ1, RQ2); in which dimensions of the research framework results have been obtained (RQ3, RQ4, RQ5); where they are applied (RQ6); and which performance indicators are considered for the management of business processes (RQ7). As indicated previously, the SLRs reviewed have not enabled us to respond to the majority of these research questions (see Table 1).

## 4.3 | Search strategy

The definition of the search strategy consists of specifying the search string, the period that will be analysed, and the sources to which the search will be applied.

- Search string

The term "Green BPM" would appear to be the most obvious search string for this research, but the SLRs consulted state that there are not many publications on this subject. The research problem was, therefore, broken down into individual elements in order to obtain the principal search terms (Green and BPM). We also identified synonyms of the principal terms (sustainable and sustainability) or the meaning of the abbreviation (business process management). Moreover, we used the Boolean "OR" to incorporate the synonyms and meanings of the abbreviations and the Boolean "AND" to unite the principal terms found.

The search string used was, therefore,

(Green OR Sustain*) AND (BPM OR "Business Process Management")

- Period

The period studied covered 1990 to April 2016 with the aim of discovering any previous works that might contribute to the knowledge regarding the relationship between environmental sustainability and business process management.

- Sources

The search was carried out in the digital libraries to which we had access (IEEE Digital Library, ACM Digital Library, SprigerLink, ScienceDirect, Web of Science, Google scholar, MDPI - Open Access Publishing Scopus), and the types of contributions selected were journals, conferences, workshops, technical reports, and other electronic publications. We also took into account the primary studies considered in other SLRs.

## 4.4 | Inclusion/exclusion criteria

The study selection criteria used to determine those studies that should be included in or excluded from the systematic review are shown in Table 2, which presents the exclusion criteria that were applied to the results obtained after using the search string in the sources selected, along with the criteria employed to include a work in the study.

## 4.5 | Strategy used to assess the quality of studies

The evaluation of the quality of the study is relevant in each step of a review. The study selection criteria determine the minimum acceptable level of the design, but the studies selected should be subjected to a more refined control of their quality using other methods. The references employed to evaluate quality in this work are the criteria of[22,23]

1  Reports: The study reflects the results of a piece of research in which a research goal is clearly proposed, and the context in which the research will take place is clear.

**TABLE 2**  Inclusion and exclusion criteria

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| • Relevance with regard to research questions.<br>• Explicitly mentions the green approach or sustainability for BPM, even if the term Green BPM/Green business process management does not appear.<br>• Study in the form of scientific articles, book chapters or research reports. | • Study that is not written in English.<br>• PhD theses, research reports, event books, event promotions, class notes, websites, prefaces, or editorials, because they are not usually subjected to peer reviews.<br>• The full text is not available in electronic format or has not been accessed.<br>• Duplicate studies with equal or different levels of depth. In the first case, the duplicates are excluded and in the second, the most complete one is chosen.<br>• The document is some kind of review of what has been published on the subject and does not include specific results. |

2 Rigour: The design of the research is appropriate for the research goals, and the data found are analysed in a rigorous manner.

3 Credibility: The findings are clearly presented.

4 Relevance: The value of the study as regards the research questions formulated in the work.

Figure 4 shows the relationship between the inclusion/exclusion criteria and the quality criteria. All of the quality criteria are widely covered by the inclusion and exclusion criteria, which make it possible to evaluate the quality of what is reported in the study, along with its rigour, credibility, and relevance

## 4.6 | Data extraction strategy

Another important aspect is the definition of relevant information that will serve to respond to the research questions formulated. The data extracted from each of the works selected (together with the related research questions) are title (RQ1 and RQ2), author (RQ1), publication (RQ1), language (RQ1), type of publication (RQ1), research approach (RQ1), year (RQ1), definition of Green BPM (RQ2), process life cycle (RQ3), management activities (RQ4), goals of Green BPM (RQ5), context in which Green BPM is applied (RQ6), and KEIs or EPIs (RQ7).

Bearing in mind the types of research that can be produced, we decided that the works should be classified as follows:

- Development: works that are principally focused on describing how sustainability can be incorporated into some of the stages of the management activity process life cycle.
- Application: works that apply some of the stages of the life cycle or the management activities in different business domains or contexts with the aim of evaluating the proposal.
- Validation: works in which a proposal is applied in order to validate how the ecological approach has impacted on BPM.
- Theoretical analysis: works that present considerations regarding the subject on the basis of the literature reviewed and the authors' experience.

Moreover, we have also classified the works on the three dimensions so as to characterise the fields of action that exist in Green BPM (Figure 3) proposed in Opitz et al[5] and have adapted them to our context as follows:

- The BPM life cycle considers design contributions, monitoring, improvement, implementation, and operation.
- The management activities considered are plan, do, check, and act.
- The goals of Green BPM considered are reduce environmental impact and cultural change.

We have also carried out an exploratory study in order to detect the EPIs or KEIs that are mentioned, such that they can serve as a reference for the proposal presented in this work. The data extraction strategy was (1) to define the metadata regarding publications and the fields that serve to respond to the research questions and (2) to classify the works according to the classification scheme defined.
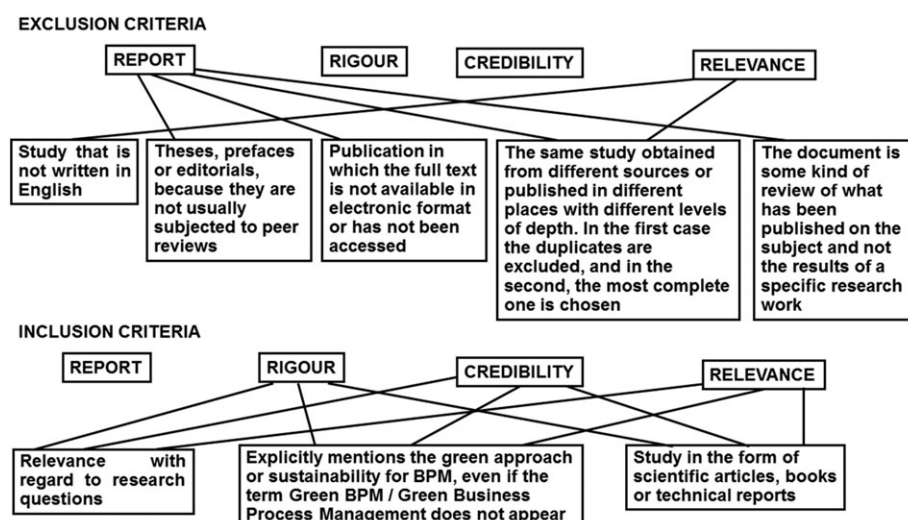


**FIGURE 4** Relationship between the inclusion/exclusion criteria and the quality criteria

The data found were synthesised by carrying out a narrative summary of the results obtained. Tables and graphs, in which the consensus or nonconsensus of the studies reviewed will be appreciated, have been used to manage and present the data and to obtain ideas.

## 5 | EXECUTION OF THE SLR

The execution of the search strategy involves carrying out all the activities, which were defined when the study was planned, and obtaining the information associated with the research questions formulated. This section is divided into two subsections. The first presents the results obtained after applying the search strategy, while the second presents the studies selected for analysis.

### 5.1 | Execution of the search strategy

The relevant publications required to respond to the research questions were obtained by applying the previously specified search string to databases. This resulted in 3219 studies, which were then itemised by type of publication and year, as shown in Figure 5.

It will be noted that the number of publications related to the search terms increased from 2009 onwards (it is worth emphasising that the search took place in April 2016). As it was possible that not all the works were relevant as regards the research questions, it was necessary to carry out the remaining tasks in the execution stage in order to obtain a true image of this classification.

### 5.2 | Select primary studies based on the inclusion/exclusion criteria and the quality assessment strategy

The strategy employed to evaluate the quality of the studies was the review protocol regarding the application of the inclusion/exclusion criteria. It was necessary to carry out the three iterations summarised in Figure 6. The first iteration enabled us to obtain 3219 publications (as the direct result of applying the search string to the various digital libraries). The left-hand side of Figure 7 shows the number of publications from each digital library.

The second iteration allowed us to reduce the number of studies from 3219 to 664. This was possible thanks to the application of the exclusion criteria and of some quality criteria on the basis of the following situations (see right-hand side of Figure 7):

- Repetition of the same titles in various sources. In three cases, we found another more complete work by the same authors, and the less complete were, therefore, discarded as repetitions (180 papers).
- Works not written in English (51 papers).
- Discovery of works in which the meaning of the term BPM was not that sought (beam position monitors, battery power modules, beats per minute, beam propagation method, best practices management, building performance model, boundary perturbation method, background process manager, behavioural perspective model, business performance management, business process model, business process modelling, process-oriented approach, and business process maintenance). Moreover, in several works, the term Green referred to the surname of
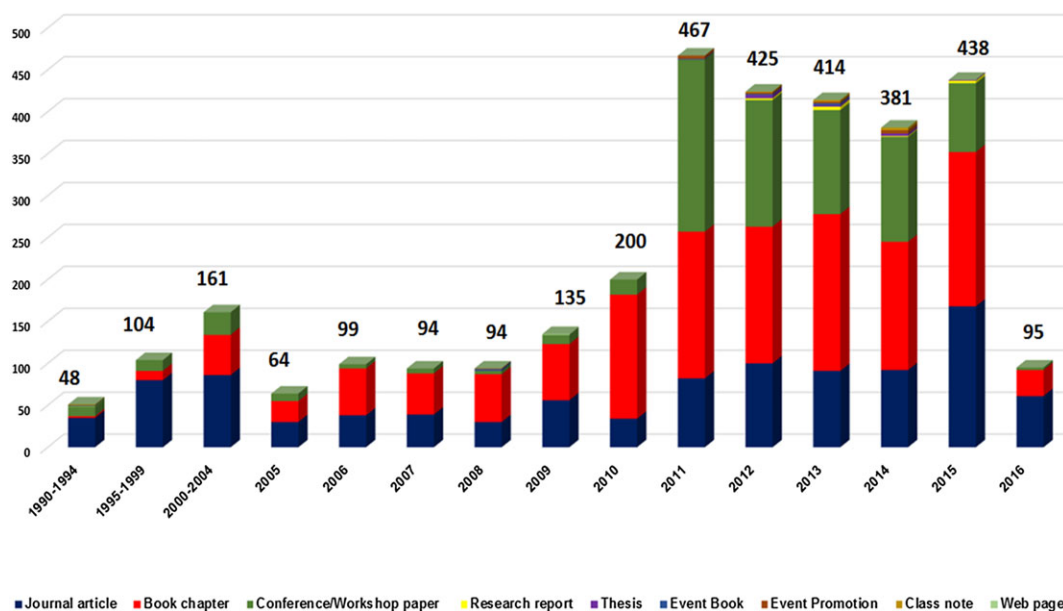


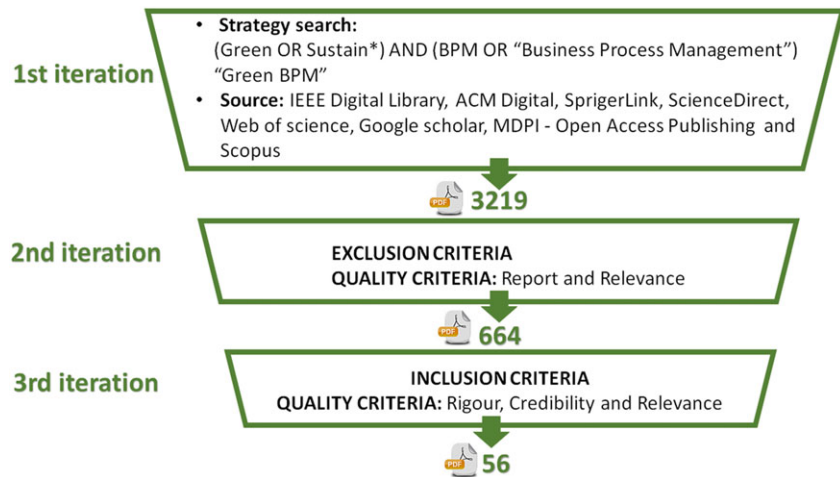**FIGURE 5**   Publications by type and year

**1st iteration**
- **Strategy search:**
  (Green OR Sustain*) AND (BPM OR "Business Process Management")
  "Green BPM"
- **Source:** IEEE Digital Library, ACM Digital, SprigerLink, ScienceDirect, Web of science, Google scholar, MDPI - Open Access Publishing and Scopus

3219

**2nd iteration**
EXCLUSION CRITERIA
QUALITY CRITERIA: Report and Relevance

664

**3rd iteration**
INCLUSION CRITERIA
QUALITY CRITERIA: Rigour, Credibility and Relevance

56

**FIGURE 6**   Iterations of the search process



**Sources**

123  40  30
139
499  674
338
1376

- ACM
- IEEE
- Science Direct
- SpringerLink
- Scopus
- Wos
- MDPI
- Google scholar

**Application of the exclusion criteria and of the quality criteria**

2426

180  Repeated
51  No English
2426  Other meanings of BPM and Green
29  States of art or SLR
69  Other types of publication
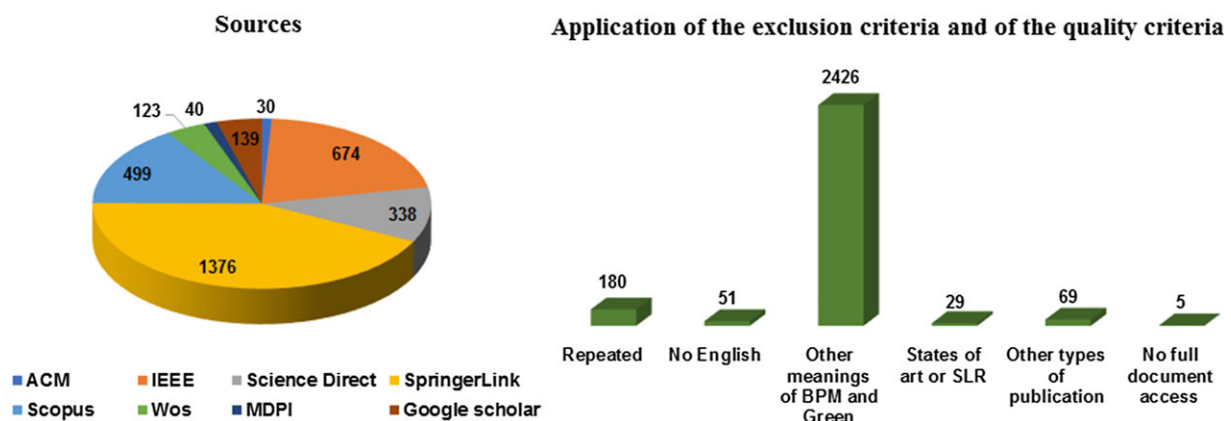5  No full document access

**FIGURE 7**   Search results

one of the authors of the research or to the colour, or was a bibliographical reference, while "sustainability" concerned a proposal that was based on or founded on something, or referred to something that could last over time (2426 papers).

- States of the art or systematic literature reviews (29 papers).
- Other types of publications: presentations of events, class notes, websites, and lists of works at an event (69 papers).
- Works whose complete text we were unable to access (5 papers).

It is worth emphasise that some papers fit in more than one of the exclusion criteria, reason why the final set is 664 paper and not exactly the difference between the number of recovered papers and papers that fitted in any of the exclusion criteria.

This iteration also enabled us to discover an SLR that was not classified as such.[6] The authors of this SLR focused on 36 primary studies that were considered to deal with information systems and BPM. For each study, they identified what the information systems focused on, considering organisational factors (management and strategy) and the indicators of environmental impact dealt with (energy consumption, measurement of the $CO_2$ footprint, and greenhouse gas emissions). The authors identified challenges for future studies in the context of information systems, but did not explore the subject of Green BPM in any depth. In the case of extensions to the definition of the concept of Green BPM, they stated that only two (6%) of the works found made any contribution. This work was discarded because it was a review and because its content did not serve to respond to the questions formulated. Despite having found this new SLR, we were of the opinion that the opportune nature of and need for our SLR were still valid and, therefore, decided to continue with it.

The third iteration allowed us to reduce the number of studies selected from 664 to 56 after applying the inclusion criteria and evaluating the quality criteria associated with rigour, credibility, and relevance. There were doubts as to whether to include nine works, and this led to the intervention of the expert reviewer, who considered that six of them should be selected for the study. Fifty-three works were consequently attained.

Moreover, the snowballing process described in Wohlin[24] was applied to these results. This process implies continuing to search on the basis of the works cited by the publications that the reviewer considers to be of interest. Four works were identified, but we were unable to access the complete text of one of them, signifying that only three were included in the list of primary studies.

We, therefore, eventually obtained a set of 56 primary studies,[3,13,14,17,25-76] which will be analysed in the following subsections.

## 5.3 | Studies selected for analysis

With regard to the types of papers defined in Section 4.6, 20% of the 56 primary studies selected were theoretical analyses, 7% were validations, 43% concerned application, and 73% concerned development. As will be appreciated, some works used more than one approach, but the majority focused on proposing how to incorporate sustainability into some of the stages of the life cycle of the process or the management activities. Less than 50% of the works applied what they had formulated in order to evaluate the proposal.

Part of the process of responding to each of the questions consisted of creating a narrative summary of the primary works related to each question. This summary is provided in the following sections.

# 6 | SLR REPORT: RESULTS OBTAINED

This section presents the results obtained after carrying out the systematic literature review. The results were analysed on the basis of the questions presented in Section 4.2.

Table 3 shows the 56 primary studies reviewed and the data that allowed us to answer the questions posed. This information will be used as a basis on which to present the conclusions reached regarding how each aspect has been analysed in the selected works.

These conclusions are shown in the following subsections.

## 6.1 | RQ1: How have the published works associated with Green BPM evolved?

This question was formulated with the intention of evaluating how the subject of Green BPM has evolved and bearing in mind that the authors of the SLR mentioned in Subsection 4.1 state that there are few works in this field. Figure 8 summarises the publications selected by type and year.

As can be observed, most of the research linked to this subject was published in 2011 and 2012. This was, fundamentally, for two reasons. In 2011, there was an explosion of works summarising the research carried out that was inspired by the challenges proposed in Ghose et al.[17] These were presented at events or published in books related to this subject. The second reason was the publication of the book entitled _Green Business Process Management: Towards the Sustainable Enterprise_[77] in 2012. This was a compilation of the works carried out until that moment in that field, grouped in three parts: "Foundations and Directions," "Tools and Methods," and "Cases and Examples."

Although not directly related to the research question, we decided to seek information related to the authorship of the selected publications. Figure 9 shows authors with more than one piece of work. Note that some authors are recurrent in this research. This evidences that the subject is in the first phases of research and that few groups are working on it.

Many references are made to Green BPM between 2013 and 2016, although not to the same extent as in 2011 and 2012 for the reasons mentioned above. It is, however, encouraging that 40 of the 46 authors and coauthors of these 21 studies (87%) have had work on this subject published in the last few years.

## 6.2 | RQ2: How has Green BPM been defined in literature?

Conceptualising the term "Green BPM" is a first sound step towards motivating an organisation to adopt a Green process. The objective of this question is to investigate how it has been defined and to identify whether there is any consensus as to its definition.

The term may be recent, but the relationship between sustainability and business is not. According to Hui Zhang et al,[78] the sustainable development of companies implies adopting business strategies and activities that will satisfy the needs of both organisations and any interested parties, while sustaining and improving the human resources and materials that it will require in the future.

In Bocken et al,[79] Green BPM is defined as a business model that is sustainable as regards to innovations that make significant positive and/or negative impacts on the environment by means of changes in the way in which organisations create value or change their propositions concerning value. In Schmidt et al,[76] meanwhile, a business model can be interpreted as Green if it primarily pursues environmental objectives under the minimum constraint of cost-coverage.

The systematic review described in Ghose et al[17] contains common terms that attempt to define the subject of sustainability and the company. Keywords, such as "environment," "business process," "measure," and "evaluation" were recurrent and served as a basis on which to propose a definition. For these authors, Green BPM is the sum of all IS-supported management activities that help to monitor and reduce the environmental impact of business processes in their design, improvement, implementation, or operation stages, in addition to leading to cultural change within the process life cycle.

The definitions of Green BPM provided by the various authors of the works selected are shown in Table 4.

The remaining works generally assume and reference the proposals of Seidel et al[3] and Ghose et al[17] when referring to the term Green BPM. The latter publication is considered to be the first to have tackled the subject of Green BPM and to have explicitly established a relationship between the terms "Green" and "BPM."

Very few authors have formalised a definition of Green BPM, and the ideas on which they agree are the following:

**TABLE 3** Findings found in the primary studies

| Reference | Definitions of Green BPM | The BPM Life Cycle | | | | | Types of Research | | | | Management Activities | | | | Goals of Green BPM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Supervision | Improvement | Implementation | Operation | Development | Application | Validation | Theoretical Analysis | Plan | Do | Check | Act | Reduce Environmental Impact | Culture Change |
| Rozman et al[70] | X | X | | | | | X | | | | X | | | | | X |
| Peko et al[61] | | | | X | | | X | | | | X | | | | X | X |
| Houy et al[71] | X | X | X | X | X | X | X | X | | | X | X | X | X | X | X |
| Nowak et al[43] | | X | X | X | | | | X | | | | X | X | | X | X |
| Wati and Koo[46] | | | X | | | | X | | | X | X | | | | X | X |
| Nowak and Leymann[56] | | X | | | X | | X | | | | X | X | | | X | X |
| Lee et al[81] | | | | X | | | | | X | | | | | X | X | X |
| Nowak et al[60] | | | | | X | X | | X | | | X | X | | | X | |
| Ta et al[39] | | | | X | | | | | | X | X | | | | X | X |
| Cappiello et al[66] | | X | | | | | X | X | | | X | X | X | | X | X |
| Hoesch-Klohe and Ghose[68] | | | | X | | | X | | | | X | | | | | X |
| Seidel et al[38] | | X | | X | X | X | | | | X | X | | | | X | X |
| Hoesch-Klohe and Ghose[37] | | | X | | | | X | | | | X | | | | X | |
| Muñoz et al[36] | | | S | X | | | X | X | | | X | X | X | | X | X |
| Nowak et al[35] | | | | | | X | X | X | | | X | X | | | X | X |
| Donnelly et al[50] | | X | X | X | X | X | X | X | | | X | X | X | X | X | |
| Schmidt et al[76] | | X | | | | X | | | X | | | X | | | X | |
| Watson et al[44] | | X | X | X | | X | X | X | X | | X | X | X | X | X | |
| Unhelkar[72] | X | X | | | | | | | | X | X | | | | X | |
| Hoesch-Klohe and Ghose[34] | | X | | | | | X | X | | | X | X | X | X | X | X |
| Gräuler and Teuteberg[49] | | | | X | | | X | X | | | X | X | X | X | X | X |
| Wesumperuma[53] | | X | | | | X | X | X | | | X | X | X | X | X | X |
| Seidel et al[3] | X | X | | | | | X | | | X | X | | | | X | X |
| Ghose et al[17] | | X | X | X | X | X | X | X | | | X | X | X | X | X | X |
| Kuppusamy and Gharleghi[45] | | | | X | X | X | | X | | | | X | | X | X | |
| Nowak et al[74] | X | X | | | | | X | | | | X | X | | | X | X |
| Nowak and Leymann[55] | | X | | | | | X | | | | X | | | | X | |
| Loos et al[75] | X | X | X | X | X | X | | | | X | X | | | | X | X |
| Thies et al[42] | X | | X | | | | X | X | | | X | X | X | | X | X |
| Seidel and Recker[14] | | X | X | | | | X | X | | | X | X | | | X | |

**TABLE 3** (Continued)

| Reference | Definitions of Green BPM | The BPM Life Cycle | | | | | Types of Research | | | | Management Activities | | | | Goals of Green BPM | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Design | Supervision | Improvement | Implementation | Operation | Development | Application | Validation | Theoretical Analysis | Plan | Do | Check | Act | Reduce Environmental Impact | Culture Change |
| Azevedo et al[33] | | X | X | X | X | X | X | X | | | X | X | X | | X | X |
| Trappey et al[62] | | | | | | X | X | | | | X | X | X | X | X | X |
| Wang et al[32] | | X | X | X | | X | X | | | | X | | | | X | X |
| Shrake et al[64] | | X | X | | | | X | X | | | X | X | X | X | X | X |
| Hoesch-Klohe and Ghose[48] | | | | | X | X | X | X | | | X | X | X | | X | |
| Cleven et al[31] | | X | X | | | | X | | | | | X | | | X | |
| Olsson et al[30] | | X | | | | | | | | X | X | X | | | X | X |
| Zeise et al[41] | | | X | | | | | | | | | | X | | X | X |
| Recker et al[54] | | X | X | X | X | X | X | X | | | X | X | X | X | X | X |
| [57] | | X | | X | X | X | X | | | | X | X | X | | X | X |
| Lübbecke et al[52] | | | | X | X | X | X | X | | | X | X | X | X | X | X |
| Xianyong and Yinfeng[29] | | | X | X | | | | | | X | X | | | | X | X |
| Betz[47] | | X | X | X | X | X | X | | | | X | | | | X | X |
| Ahmed and Sundaram[65] | | X | X | X | | | X | | | | X | | | | X | X |
| Betz and Caporale[28] | | X | | X | X | X | X | | | | X | X | | | X | X |
| Nowak et al[58] | | X | X | X | X | X | X | | | X | X | X | | | X | X |
| De Soete[59] | | | X | b | b | b | X | | | | X | X | | | X | |
| Jakobi et al[27] | | X | | | | | X | | | | X | | | | X | X |
| Lübbecke et al[69] | X | X | X | | | | X | X | | | X | X | X | | X | |
| Houy et al[73] | X | X | X | X | X | X | | | | X | X | X | X | | X | |
| Hoesch-Klohe et al[13] | | X | | | | | X | | | | X | | | | X | |
| Reiter et al[51] | | | X | | | | X | X | | | X | X | | | X | X |
| Hailemariam and vom Brocke[67] | | | | X | | | X | X | | | X | X | X | | X | X |
| Opitz et al[26] | | X | | | | | X | X | X | | X | X | X | | X | |
| Nowak et al[25] | | | X | X | | | | | | X | X | | | | X | X |
| Hasan[63] | | X | | X | X | X | X | | | | X | X | | | X | X |

**TABLE 3** Findings found in the primary studies

| | KEIs or EPIs | | | | | | | | | Application Contexts of Green BPM | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Recycling | Use of Resource | Energy Efficiency | Use of Ecological Resources | Emissions | Waste Products | Reuse | Pollution | Biodiversity | Manufacturing | Construction Industry | Public Sector | Service Industry | TIC Industry | Supply Chain Management |
| Rozman et al[70] | | | | | | | X | | | | | | | | |
| Peko et al[61] | | X | X | | | | | | | | | | | | |
| Houy et al[71] | | X | X | | | X | | | | | | | X | | |
| Nowak et al[43] | | X | X | | X | | | | | X | | | | | |
| Wati and Koo[46] | | X | X | | X | | | | | | | | | | |
| Nowak and Leymann[56] | X | X | X | X | | | | X | | | | X | X | X | |
| Lee et al[81] | | X | X | X | X | | | | | X | X | | | | |
| Nowak et al[60] | | | X | | X | | | | | | | | | | |
| Ta et al[39] | X | X | X | | X | X | X | X | | | | | | | |
| Cappiello et al[66] | | X | X | | | | | | | | | | | | |
| Hoesch-Klohe and Ghose[68] | | X | X | | | | | | | | | | | | |
| Seidel et al[38] | | X | X | | X | | | | | X | | | | | |
| Hoesch-Klohe and Ghose[37] | | X | | | X | X | X | | X | | | | | | |
| Muñoz et al[36] | | X | X | X | | | | | | X | | | | | |
| Nowak et al[35] | | X | X | | | | | | | | | | | X | |
| Donnelly et al[50] | X | X | X | X | X | | | | | X | | | | X | |
| Schmidt et al[76] | | | X | | X | | | | | | | | | X | |
| Watson et al[44] | X | X | X | X | X | X | | | | X | | | | | |
| Unhelkar[72] | | | X | | X | | | | | | | X | | X | |
| Hoesch-Klohe and Ghose[34] | | X | | | X | | | | | X | | | X | | |
| Gräuler and Teuteberg[49] | | | X | | X | | | | | | | | X | | |
| Wesumperuma[53] | | X | | | X | | | | | X | | | | | |
| Seidel et al[3] | | | | X | X | X | | X | | | | | | | |
| Ghose et al[17] | | | X | | X | X | | | | | X | | | | |
| Kuppusamy and Gharleghi[45] | | | | | | | | X | | | | | X | X | |
| Nowak et al[74] | | | | X | X | X | | | | | | | X | | |
| Nowak and Leymann[55] | | | | | X | X | | | | X | | | | | |
| Loos et al[75] | X | X | X | | X | | | | | | | | | | |

**TABLE 3** (Continued)

| | KEIs or EPIs | | | | | | | | | Application Contexts of Green BPM | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reference | Recycling | Use of Resource | Energy Efficiency | Use of Ecological Resources | Emissions | Waste Products | Reuse | Pollution | Biodiversity | Manufacturing | Construction Industry | Public Sector | Service Industry | TIC Industry | Supply Chain Management |
| Thies et al[42] | | X | | | X | | | | | | | | X | | |
| Seidel and Recker[14] | | | X | X | X | X | | | | | | | X | | |
| Azevedo et al[33] | | | | | X | X | | | | | | | | | X |
| Trappey et al[62] | | | X | X | X | X | | | | X | | | | | |
| Wang et al[32] | | | X | X | X | | | | | | | | | | |
| Shrake et al[64] | | X | X | | X | | | | | | | | X | | |
| Hoesch-Klohe and Ghose[48] | | | | X | X | X | | | X | | | | X | | |
| Cleven et al[31] | | | X | X | X | | | | | | | | | X | |
| Olsson et al[30] | | | X | | X | | | | | | | | X | | |
| Zeise et al[41] | | | | | X | | | | | | | | | | |
| Recker et al[54] | | | | | X | | | | | | | | X | | |
| 57 | | X | | | | | | | | | X | | | | |
| Lübbecke et al[52] | | | X | | X | | | | | | | | X | | |
| Xianyong and Yinfeng[29] | | X | X | | | | | | | | X | | | | |
| Betz[47] | | | X | | X | X | | | | | | | | | |
| Ahmed and Sundaram[65] | | | | | X | | | | | | | | | | |
| Betz and Caporale[28] | | | X | | X | X | | | | | | | | X | |
| Nowak et al[58] | | X | X | | X | | | | | | | | X | | |
| De Soete[59] | | | X | | X | | | | | X | | | | | |
| Jakobi et al[27] | | | X | | | | | | | | | | | | |
| Lübbecke et al[69] | | | X | | | | | X | | | | | X | | |
| Houy et al[73] | | X | | | | X | | | | | | | X | | |
| Hoesch-Klohe et al[13] | | X | | | X | X | | | | | | | | | |
| Reiter et al[51] | | X | | X | | | | X | | | | | | X | |
| Hailemariam and vom Brocke[67] | | | | | | | | | | | | X | | | |
| Opitz et al[26] | | X | X | | X | | | | | | | | | | |
| Nowak et al[25] | X | X | X | X | X | | | | | | | | | | |
| Hasan[63] | | X | | | X | X | | | X | | | | | | |

**FIGURE 8** Publications selected by type and year
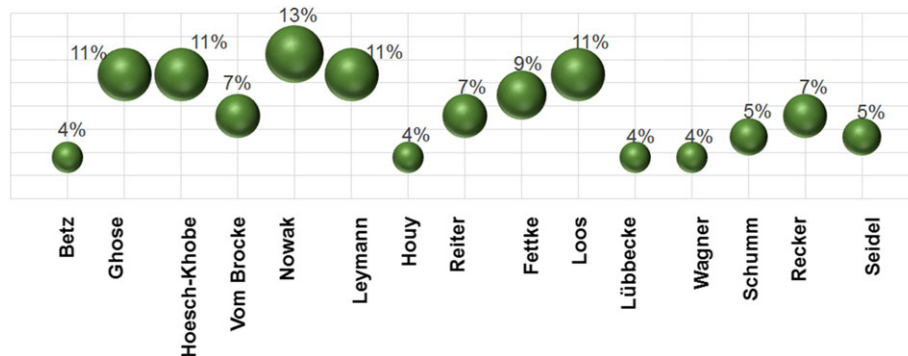


**FIGURE 9** Percentage of author participation (those with more than one work)

- It has its origin in the interception of approaches and ideas from the fields of BPM and Green IS, which is why Green BPM is not conceived without IT.

- It causes changes in the life cycle of a business process, adapting the definition, execution, monitoring, and improvement, so as to cover all dimensions of sustainability (economic, social, human, and environmental). In particular, it optimises these processes in order to reduce the environmental impact of their activities.

All of the aforementioned definitions contribute with elements that are relevant to the characterisation of what Green BPM is (Figure 10), thus making it possible to propose a definition for Green BPM.

*Technology that extends BPM technology in order to define, implement, operate, monitor and improve business processes, considering all those dimensions that facilitate sustainable development (social, environmental, human, economic and technical), placing emphasis on environmental objectives. Its application by an organisation implies the optimisation of existing processes, the use of information technologies and information systems as a support during all the stages of the BPM lifecycle and a greater commitment to biodiversity and to economic and social progress.*

This definition of Green BPM considers the stages of the BPM life cycle. Research into those stages for which environmental sustainability has already been contemplated, and how this has been done, is carried out in the following subsection.

## 6.3 | RQ3: Which stages of the process life cycle are involved?

The BPM life cycle is one of the dimensions of the framework proposed by Opitz et al[5] (Figure 3). It includes the design, monitoring, improvement, implementation, and operation stages. Incorporating the term "Green" into BPM should have an impact on the way in which each of them is carried out. The purpose of this question is, therefore, to discover whether new methods, techniques, and tools have been developed for this purpose, or whether the existing ones have been adapted.

All the stages in the life cycle of a process have been the object of study of the research analysed (see Figure 11), although the greatest efforts have concentrated on the design (52%), monitoring (45%), and improvement stages (45%). This is logical if we consider that it is vital to model and represent an organisation's processes as a basis for the remaining stages. The implementation and operation stages are approached in 29% and the 39% of the works, respectively.

The idea of proposing or using a framework that contains a standardised set of concepts, practices, and criteria that will serve as a reference with which to integrate sustainability into business process management has been recurrent since the appearance of the first works linked to this subject.[17,59-68,71]

**TABLE 4** Green definitions

| Source | Definition |
|---|---|
| Green business process management: A research Agenda[17] | We will use the term "Green BPM" to describe a new type of technologies that leverage and extend existing BPM technology to enable process design, execution, and monitoring in a manner informed by the carbon footprint of process designs and instances. |
| Green IT: A matter of business and information systems engineering?[75] | Green BPM incorporates sustainability as an objective and as a vehicle for managing business process change. |
| Green business process patterns[74] | The so-called Green BPM deals with the optimisation of business processes based on the four common dimensions, cost, quality, time, and flexibility, and in particular also considers a fifth dimension: the ecological dimension. This dimension covers a variety of aspects, such as energy consumption, water consumption, or the production of waste incurred during the performance of business processes and activities contained therein, respectively. |
| Towards Green BPM sustainability and resource efficiency through business process management[73] | Techniques and tools resulting from the adaptation of BPM techniques and tools to Green IT requirements in order to model, implement, execute, and monitor processes. |
| Green business process management[3] | Green business process management concerns the understanding, documenting, modelling, analysing, simulating, executing, and continuous change of a business process with dedicated consideration paid to the environmental consequences of these business processes. |
| Enterprise Green IT strategy[72] | Green business process management (BPM) is when an organisation models, studies, and optimises its processes in order to improve its Green credentials. This work involves optimising existing processes and introducing new greenaware processes that will not only reduce carbon emissions but also enhance the customer's experience. |
| Advancing business process technology for humanity: Opportunities and challenges of Green BPM for sustainable business activities[71] | "Green BPM" as an intersection of approaches and ideas from the fields of BPM and Green IS. Green BPM is supposed to provide techniques for the design, execution, control, and analysis of sustainable processes in many different application areas. |
| Achieving sustainable development by integrating it into the business process management system[70] | Sustainable BPM means that we take a process-oriented approach to an organisation's primary way of management and we continuously refine, measure, and optimise processes. Implementing sustainability aspects in BPM means that we reengineer existing processes or introduce new ones in our organisations, which cover all the sustainability dimensions (economic, social, and environment). |
| Towards ecological workflow patterns as an instrument to optimise business processes with respect to ecological goals[69] | The objective of Green BPM is to design and optimise IT-related processes with regard to ecological objectives such as the resource consumption of business processes. The sustainability of processes refers to the consumption of electric energy, the emission of pollutants, or the consumption of resources as a result of the execution of a process. |
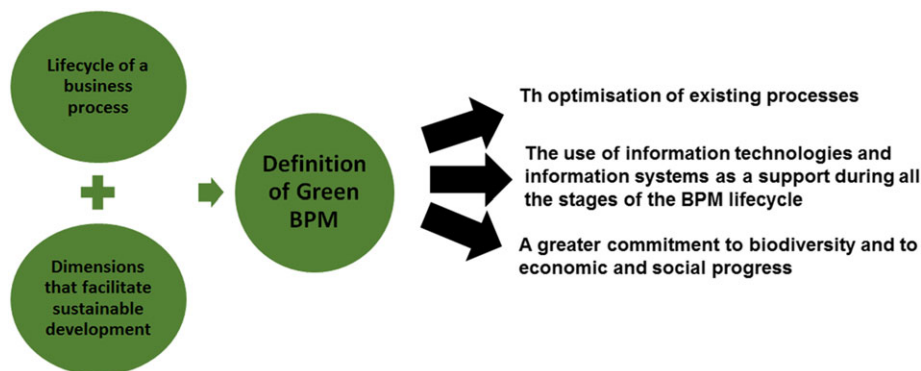


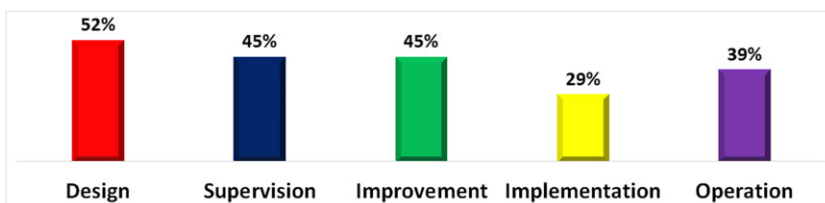**FIGURE 10** Relevant elements to characterise "Green BPM"



**FIGURE 11** Process stages distribution systematic review results

In Houy et al,[73] the authors identify the potentials of Green BPM in the life cycle as regards the continuous improvement associated with each of the stages proposed by authors in the aforementioned works: the development of a strategy, definition and modelling, implementation, execution, monitoring and control, and optimisation and improvement. The principal changes that should be made to the traditional BPM life cycle for it to be ecological are defined in Nowak et al,[58] and this can be achieved by incorporating new elements or extending the traditional BPM. These new elements include the definition of a new stakeholder, the ecological officer, whose main function is to design the KPIs in accordance with the organisation's strategic objectives and define which methods will be used for measurement purposes and which strategy to follow in order to adapt the business process to these indicators. These authors consider that the use of a service-oriented architecture is appropriate as regards determining the various ecological metrics and correlating them with the information concerning the execution time of the business process. In the extension of the architecture, they add new services in order to determine ecological indicators, monitoring facilities, an ecology management dashboard, and methods and tools for the analysis and adaptation of ecological processes.

New patterns, classified as basic patterns (used over the business process, thus signifying that it is not necessary to change the structure of the business processes), process-centred patterns (which change the structure of the process, along with the way in which the activities are carried out), and patterns focused on supply (which are focused on distributing the processes and activities among the associates with the aim of improving the global impact on the environment), are defined in Nowak et al.[74] The authors include suggestions concerning how to support the decisions made regarding the most suitable patterns to use in each case.

Another line of research concerns the cloud patterns associated with supporting the implementation and optimisation of business processes.[57]

In order to provide examples of the fact that an alternative could be the adaptation of known patterns, Nowak and Leymann[56] use variations of existing patterns for other domains (specifically, data flows, application architectures, and architectures in the cloud). The work in Nowak and Leymann,[55] meanwhile, refers to four patterns that are focused on how to integrate the services implemented in order to construct an enterprise's value flow.

An extension of BPM to demonstrate how existing analysis tools for an organisation's management can be adapted in order to allow the inclusion of sustainability-related considerations is described in Recker et al.[54] This extension makes it possible to indicate the impact of an activity on the emission of $CO_2$, along with the "source of the emission" and the "$CO_2$ production method"; attach a symbol representing a source of emission, such as fuel or paper, to each activity; use colour coding to provide information about how the emission of greenhouse gases is progressing or the final consumption for each swim lane or group created; and represent the flow of greenhouse gases in a process by connecting the emission-producing activities with emission indicators.

A framework that integrates sustainability with adaptive approaches for complexity and uncertainty, such that a company can be both adaptable and sustainable, is proposed in Peko et al.[61] The proposal includes the context, framework, life cycle, architecture, and prototype implementation, all of which form an adaptive sustainable business model. The authors emphasise that a company of this type will have a resilient viewpoint, ie, their products will be "built to last."

Information systems and information technologies support many business processes, and establishing the traceability of the business activity, the applications that support it and the hardware components that participate may, therefore, contribute to monitoring the use and consumption of this type of resources. A software prototype that implements a conceptual integration model in which the layers that participate (business process, application, and hardware) and the integration among them are clear is described in Reiter et al.[51]

One of the good practices employed in some businesses has been that of considering ecorequirements at the same level as the requirements of the products and/or services that the business produces, thus enabling them to be inserted naturally into the process.[50] One way in which to reflect this new type of requirements is to annotate the activities with the requirements.

Various authors tackle the importance of marking the activities with the quantity of $CO_2$ emissions that they produce when they are executed or the resources that are used during their execution. Some of them, therefore, propose extensions to the BPMN.[37,49,54] Other authors suggest the use of XML-Nets,[47] and some do not use any standard modelling language.[48,66,74,77]

Cappiello et al[66] present an extension of the conceptual model of the business process in order to capture the energy consumed by business tasks. This is done by monitoring the components of a service centre in accordance with the Green performance indicators. This proposal makes it possible to identify where energy leaks or violations occur, thus facilitating improvements to processes. This annotation is not sufficient as regards considering all the possibly associated ecorequirements. Figure 12 shows the elements that can be added to the activity specification. Some of them can be represented visually (e.g., emissions and energy consumption), while others are part of the detailed description of the activities, sub-activities, processes or businesses (e.g., good Green practices).

Another recurrent theme in various works is the use of information technology to strategically facilitate the reduction in carbon emissions of not only the information technology systems but also the entire organisation.[3,46,49,51,65,72,75] Simulation as a technique by which to visualise how processes operate and the impact of changes is proposed in various research works.[47,53]

A general conclusion regarding the process stages is that the most widespread tendency is that of adapting or extending already existing methods, techniques, and tools to BPM in order to support Green BPM.

## 6.4 | RQ4: Which management activities are involved?

Figure 13 shows the reach of the primary studies characterised using the PDCA model (plan, do, check, and act model), which is associated with the management activity dimension.[5]
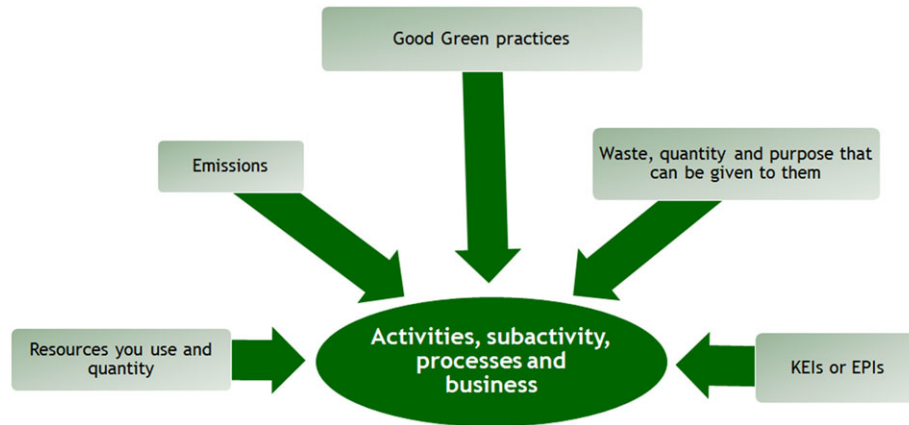
**FIGURE 12**   Elements used to annotate activities, subactivities, processes, and business
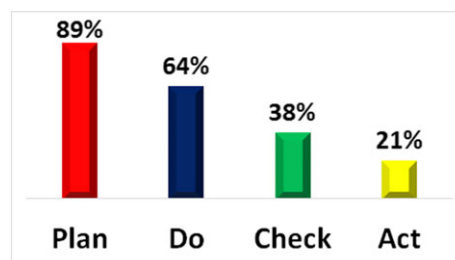


**FIGURE 13**   Management activities SLR results

The distribution of percentages is as follows: plan, 89%; do, 64%; check, 38%; act, 21%. Almost all the studies focus on defining the goals by presenting a proposal linked to one of the stages in the life cycle. Few research works propose corrective measures through which to achieve the goals. Less than half of the works evaluate the results of their proposal or propose improvements.

The impact of effective ecological business process management on manufacturing companies in Malaysia when carrying out three Green practices—monitoring, collaborating, and selecting Green suppliers—is shown in Kuppusamy and Gharleghi.[45] The authors demonstrate that supervision and selection have a positive influence on the management of Green BPM.

A case study (the Ecosia.org search engine) to show how ecological and economic objectives can complement each other is presented in Schmidt et al.[76] Ecosia.org search engine is a Green business model that has been adapted to information technologies.

Meanwhile, an approach for the sustainable environmental management of business process, denominated as Green activity based management, is presented in Wesumperuma et al.[53] The methodology helps capture, measure, model, and provide information about greenhouse gas emissions, together with other business objectives. Simulation is used to visualise how to operate the processes and the impact of the changes. Another experience regarding the use of simulation software is reported in Lübbecke et al.[52] In this case, the approach can be used to apply business process simulation techniques focused on energy consumption and the carbon footprint. It was applied to a German supplier who obtained a positive impact as regards a reduction in these indicators.

A methodology with which to model the existing process linking the sustainability factors to their activities is proposed in Wati and Koo.[46] This is later simulated, and the improvements are evaluated. The results are then used as a basis on which to transform the pattern of the original process.

In conclusion, the majority of the primary studies reviewed are limited to the definition of goals and the methods that can be employed to attain them, leaving the application of the proposal, the evaluation of the results, and the transformations with which to attain improvement as future works.

## 6.5 | RQ5: Which Green BPM goals are addressed?

The choice of carrying out Green initiatives during business process management is usually associated with two goals: reducing the impact on the environment and helping cultural change. Figure 14 shows the relationship between the research works selected and these two goals. Most of the works (96%) deal with reducing the environmental impact, while 66% are related to helping cultural change (66%).

Current social pressures and the efforts made by countries to comply with the sustainable development objectives contained in the UN 2030 Agenda are evident as regards the goal of reducing the impact of climatic change, to which the majority of studies are committed. Our main
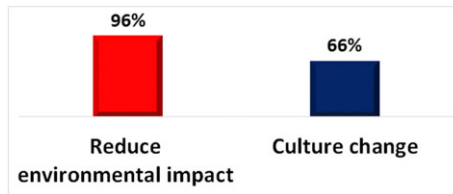
**FIGURE 14**    Green goals SLR results

conclusion regarding this aspect is that the primary studies reviewed do not always explicitly state that all interested parties must make changes to their culture in order to reduce these impacts.

## 6.6 | RQ6: In which contexts does Green BPM apply?

The objective of this question is to determine to which type of business Green BPM the work is applied. It was not easy to respond to this question, since 32% of the works do not present a proposal that is applied in either a real or a fictitious context; 18% employ hypothetical cases to exemplify or validate their proposals, and 50% mention some kind of real business. These entities are located in Australia, China, Ethiopia, Germany, Japan, Korea, Malaysia, and Sweden.

With regard to the service industry, the studies are associated with trips and transportation, consulting, income, and hospital services. They also discuss business processes associated with logistics, marketing and sales, the management of suppliers, and the selection of personnel and transport according to the business.

An example of changes made by the Frito-Lay company is presented in Watson et al.[44] The company's goal was to be more sustainable and contribute towards reducing its carbon footprint by conserving natural resources and taking advantage of renewable energies. This has been done by employing sensors throughout the business and in the control room, which monitor the consumption of certain resources. The company also has personnel who is in charge of supervising and acting according to sustainability metrics associated with the manufacturing process.

Our conclusion as regards this aspect is, therefore, that industries such as those linked to information and communication technologies and manufacturing are those to which Green BPM is typically applied in the studies consulted. However, those industries that supply some kind of service have also been attracted by the idea of adopting Green initiatives in their processes.

## 6.7 | RQ 7: Which environmental performance indicators (EPIs) or key environmental indicators (KEIs) are considered?

It is necessary to use performance indicators to measure the improvement made to sustainability-based business processes as regards activities, processes, and enterprises.[19,44,47] The objective of this question is to identify those environmental performance indicators that the studies suggest should be monitored when executing the business process.

The KEIs presented in Nowak et al[43] are formed of a tuple that consists of an ecological characteristic (metric) and an objective value function based on the ecological objectives that the company wishes to attain. Examples of KEIs are energy consumption, water consumption, paper used, residues produced, and the emission of $CO_2$.

The authors' experiences when defining software solutions that simplify the compilation, analysis, and incorporation of sustainability indicators into processes are the objective of Thies et al.[42] They present a new approach with which to share these indicators that allows the suppliers and consumers of environmental data to be connected to a common platform. The authors employ three use cases to demonstrate that a solution focused on a network with which to collect data of interest for various organisations will allow it to make the correct decisions. However, they state neither what these indicators are nor the changes or adaptations that must be made to the business processes.

Despite not including environmental impact indicators in their work, Zeise et al[41] define criteria with which to examine the performance measurement systems. They also discuss the fundamentals of sustainability measurement and possible extensions to a method that can be used to integrate sustainability into performance measurement systems and management systems.

Information regarding the relationship between the emerging field of energy computing and the management of data and processes is provided by Watson et al,[44] who consider that sustainability metrics should exist at the level of activities, processes, and enterprises, and should be continually evaluated with those related to the efficiency, costs, and quality of the company's products. This requires flow measurement sensors and a change in organisational culture and in management practices.

We have used the categorisation of indicators for the measurement of sustainability obtained for the manufacturing industry by Joung et al[19] to show those indicators that are explicitly mentioned at least once in the literature reviewed. This is shown in Figure 15 (adapted from Joung et al[19]). The classification of waste has been added, since it did not appear in the original version. The number of times that it was mentioned appears beside each indicator.
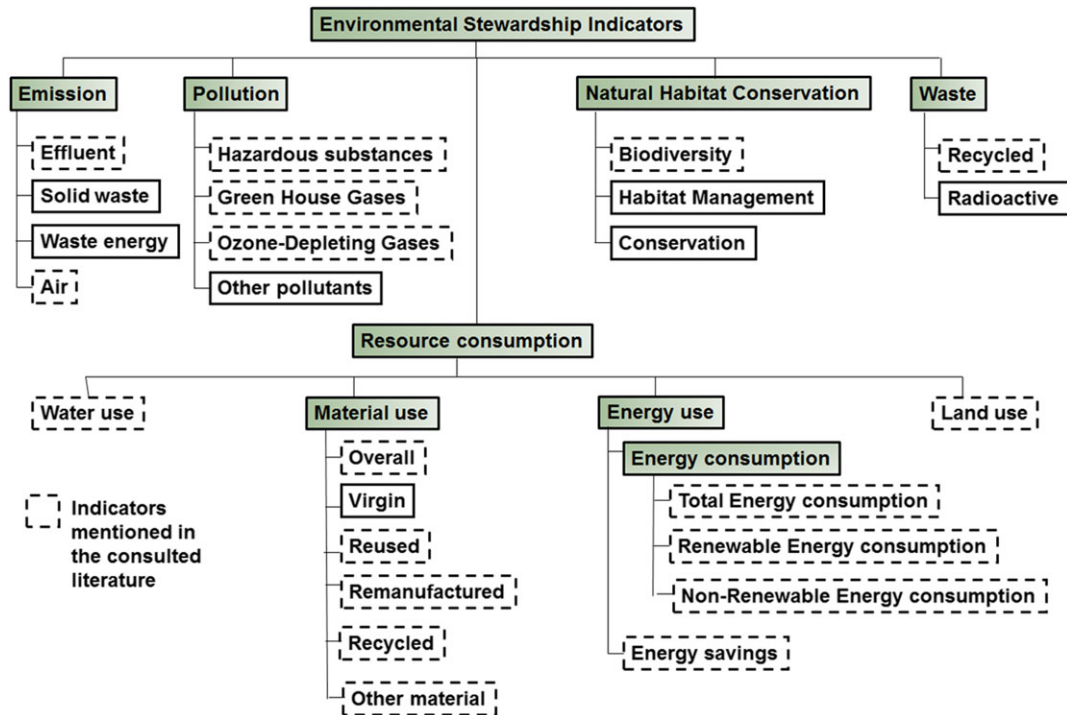
**FIGURE 15**    Indicators of environmental performance mentioned in literature

We can conclude that the most frequently mentioned indicators with which to measure environmental impact are emissions (71%), the measurement of energy consumption (61%), and the use of materials (29%). A business process obviously does not only affect the environment because of these factors, and other aspects also have an impact. The remaining indicators are mentioned to a lesser extent.

## 7 | ADDITIONAL FINDINGS

In order to deal with the environmental dimension of sustainability during the design, execution, documentation, monitoring, and improvement of the process, it is necessary to incorporate a characteristic into the quality of the process. The quality of the process influences the quality of the product or service obtained. This relationship raises the question of what the term "quality" signifies as regards business process modelling and what the interest in having a quality model for Green BPM is.

Although the questions formulated in this research do not ask whether or not a quality model for Green business process management exists, we consequently also decided to review this aspect.

The primary works obtained from our SLR did not contain any references to a quality model with which to evaluate Green BPM. We have, in general, been unable to find many works dealing with quality in business process management, and those that do exist are generally associated with software engineering processes. For example, Kroeger et al[40] present a quality model based on perspectives regarding this type of processes (Figure 16, taken from Kroeger et al[40]). This model was created on the basis of the analysis of case studies and interviews with professionals. The quality attributes of the process represent subjective judgments regarding this subject made by professionals in order to evaluate the quality of a process. Each of the attributes is defined more specifically in terms of subtypes.

With regard to sustainable software development, Calero et al[80] proposes the incorporation of the Greenability characteristic into the quality model in order to consider environmental sustainability. This concept is applied to the quality of the product and to quality in use, but not to the development process. These authors consider that Greenability represents "how" to improve quality by considering this dimension of sustainability.

Bearing all this in mind and taking into consideration the KEIs or EPI associated with a sustainable process (according to Joung et al[19]), we have proposed a new characteristic (Process Greenability) and its associated subcharacteristics (Figure 17), which we define as follows:

- Greenability. Degree of efficiency with which the process is executed in terms of environmental impact, consumption of energy, use of ecological and/or recycled resources, allocation of the required amount of resources and their use, generation of emissions, and production of waste and its destination.
- Energy efficiency. Degree of efficiency with which the business process consumes energy when executed.
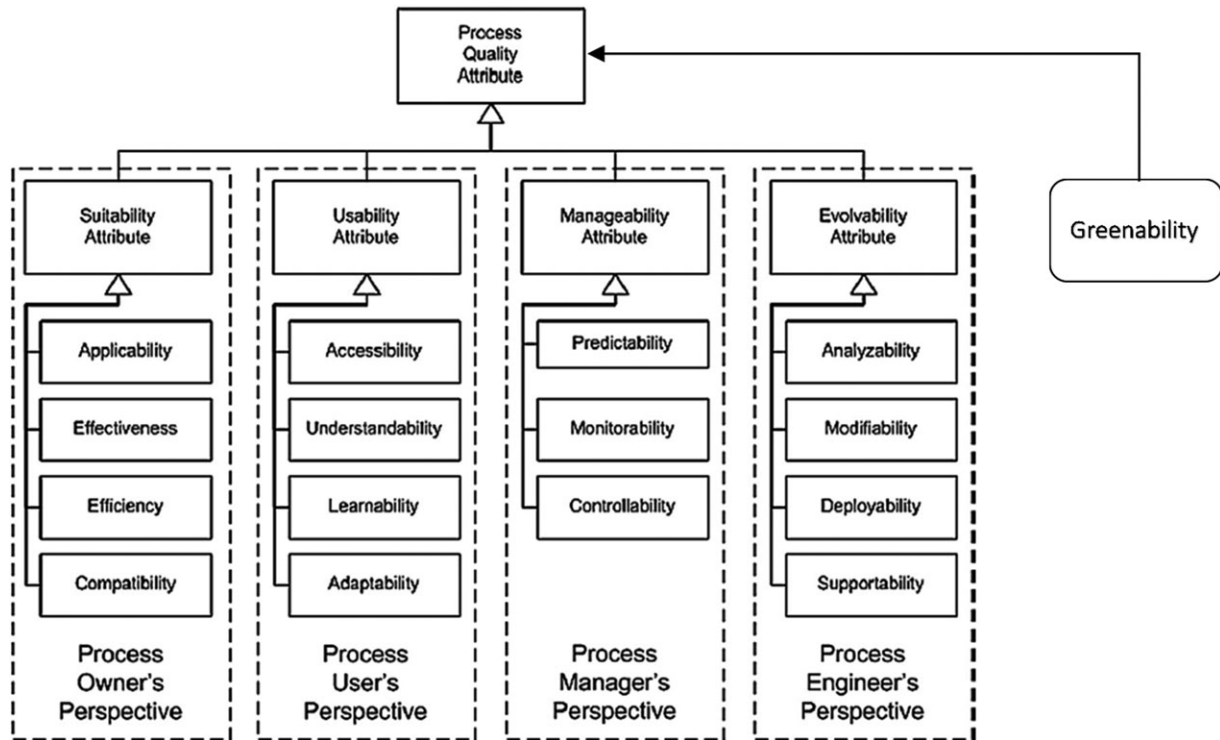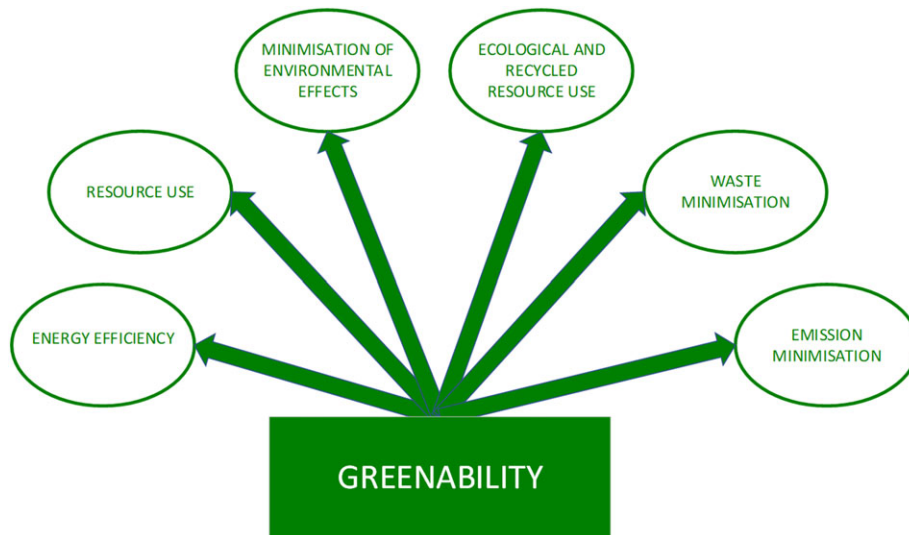
**FIGURE 16** Process quality attribute types



**FIGURE 17** Process Greenability and its subcharacteristics

- Resource use. Degree to which the exact amount of the resources required to execute a business process is allocated and used, to perform the business process functions in an optimal manner.
- Minimisation of environmental effects. Degree to which the execution of a business process reduces the effects on the environment.
- Ecological and recycled resource use. Degree to which ecological and/or recycled resources are used in the execution of a business process.
- Waste minimisation. Degree to which the business process reduces the production of waste during its execution and whether the destination of that waste is defined.
- Emission minimisation. Degree to which the execution of a business process reduces emissions.

The evaluation of the subcharacteristics requires the use of measurable attributes that have associated indicators. Figure 18 presents the relationship between the subcharacteristics defined (Figure 17) and the indicators shown in Figure 15.
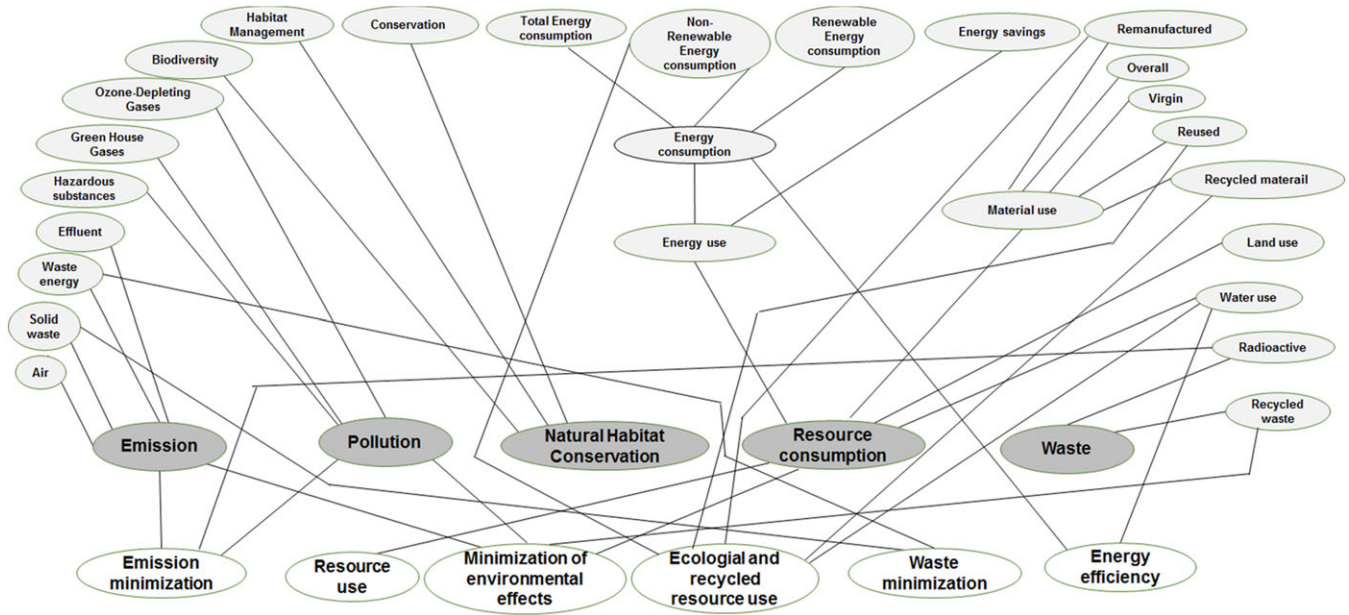
**FIGURE 18** Relationship between the subcharacteristics defined and the indicators

## 8 | LIMITATIONS

In spite of having followed the SLR methodology, we have identified the following threats to the validity of this study while developing this research:

- Papers for which we were unable to obtain a complete version since they were not available in the databases to which we had access. We used eight digital sources, which contained different types of publications, although we reviewed only those works published in journals and book chapters or presented at conferences and workshops in the field of BPM and sustainability. In fact, we had to discard only one work, and we are, therefore, of the opinion that this had no significant effect on the results obtained.

- Some subjective decisions could have been made when selecting and extracting data, since some primary studies did not provide clear descriptions, proposals, or suitable results, and this made the application of the inclusion/exclusion criteria or the impartial extraction of data more difficult. The principal researcher minimised these possible errors by reviewing the metadata constructed and the results of the first iteration tasks, which had been carried out by the other researchers. What is more, all those works about which there were doubts as regards their relevancy were reviewed by the expert reviewer.

- Classification is a potential threat, since the evaluators consider subjective factors during the analysis of the primary studies, even if these analyses are carried out by various evaluators in order to minimise distortions. Other researchers might not, therefore, attain the same classification of primary studies presented herein, although we believe that there would be few differences since all the inclusion, exclusion, and quality criteria were applied in a highly rigorous manner.

- Some studies may not have been identified in the search. In order to reduce this impact, we reviewed all the studies included in other SLRs so as to evaluate their relevance as regards the research questions formulated herein. We also examined the bibliographical references of the works as they were selected. We obtained four publications using this method, three of which were included in the primary studies.

## 9 | CONCLUSIONS

Companies should be aware of the importance of sustainability. It is, therefore, fundamental to include aspects of sustainability in their business processes and adapt them to what has been denominated as Green BPM.

This paper presents a systematic literature review carried out with the aim of encouraging the adoption of Green BPM and of obtaining an in-depth view of how Green BPM is evolving.

One of our objectives was to characterise what Green BPM is. We have done this by considering the definitions provided for this term, the stages in the BPM life cycle that have been studied, the goals that works propose should be achieved when opting for the Green initiative, the

management activities considered in the research carried out, the contexts in which they have been applied, and the performance indicators considered. All of this information has enabled us to propose a definition that synthesises those found in the literature consulted.

Another aspect that we wished to study concerned the importance placed on Green aspects in the stages of the BPM life cycle (design, monitoring, improvement, and operation), and we concluded that most attention has been paid to the first three.

With regard to the management activities (plan, do, check, and act), planning has been considered with greater frequency than the others, suggesting that future works should not to be limited to proposing and carrying out proposals, but should also evaluate the results and make the improvements required.

We have also detected that authors consider that the change to sustainable processes should be supported and promoted by information systems and/or information technologies. This is owing to the capacity of ICTs to reduce $CO_2$ emissions, thus reducing the carbon footprint of the ICT sector itself and providing applications and services that will allow businesses to manage their energy resources efficiently and control the environmental impact of their process activities. The most interesting contributions found in the literature reviewed are related to the added value of ICTs, particularly in the evaluation of key environmental impact indicators.

The most attractive proposals regarding the design stage are associated with incorporating the information activities into the resources that they use and the impact that they have on the environment in order to monitor this information during their execution and take the corresponding measures.

The principal goal proposed by those committed to Green BPM is that of reducing environmental impact. They propose the monitoring of the following performance indicators: emissions, energy consumption, and the use of materials in order to evaluate this impact.

The contexts usually chosen to exemplify a proposal for Green BPM or which are used to evaluate a real application are the manufacturing, service and information and communication technology industries.

Although the quality of business processes has not been dealt with in the studies reviewed, we consider that a quality model for business processes should currently place emphasis on the environmental dimension. An organisation that commits to process management requires a quality model with which to evaluate these processes. These are the reasons why we also decided to review the selected papers from the quality perspective. As a result, we have proposed a new characteristic (Process Greenability) and its associated subcharacteristics (energy efficiency, resource use, minimisation of environmental effects, the use of ecologically recycled resources, waste minimisation, and emission minimisation). The model provides a terminological framework that could serve as a reference when evaluating Green BPM.

Moreover, we have established the relationship between the KEIs or EPIs (as the result of one of our research questions) and Process Greenability (the characteristic defined), since the former contributes to evaluating the degree to which the latter is fulfilled.

After studying all the analyses and proposals, we can conclude that the tendency of those businesses that have committed to sustainability in their environmental dimension is related rather to the application of Green practices than to making changes to their business process management. This may be justified because there are few examples of companies that have transformed their management on the basis of Green BPM.

Bearing this in mind, our future work should be oriented towards

- Focusing more on adapting the traditional business process management techniques and methods. This will enable the incorporation of those practices that guarantee that the techniques and methods will be ecological and that can measure their environmental impact during all the phases of the life cycle.

- Empirically evaluating the changes to business modelling proposed in order to incorporate the measurement and evaluation of sustainability into all the activities in the process.

- Validating the relationship between the cost of transforming business process management and the environmental impact that it produces.

- Conceptualising the relationship between Greenability and the levels of maturity of the capacity of Green BPM.

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