Implement Green Initiative?

Benefits

Opportunities

Costs

Risks

YES

NO

PRODUCTION & MANUFACTURING | RESEARCH ARTICLE

Modeling the implementation of green initiatives: An AHP-BOCR approach

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Abstract: Over the past few decades, there has been a growing need for businesses to become more environmentally friendly in their operations, products and services. However, the decision to undertake initiatives or programs that can help them achieve this goal is complex. While there are clear and desirable ecological benefits from these efforts, it is possible that there are also negative aspects that have to be considered. Our investigation presents a theoretical model that captures the variables, processes and dynamics involved in the decision to implement/not implement a green initiative. More specifically, we propose an analytic hierarchy process model that takes into account the benefits, opportunities, costs and risks that are associated with the potential implementation of these types of programs. A simulated example shows the utility of our proposed framework. Opportunities for future research are laid out.

Subjects: Environmental Management; Research Methods in Environmental Studies; Industrial Engineering & Manufacturing; Manufacturing Engineering; Supply Chain Management; Production, Operations & Information Management; Research Methods in Management

Keywords: green initiatives; green production; green manufacturing; AHP; trade-offs; disruptive change; disruptive innovation; decision-making model; BOCR

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PUBLIC INTEREST STATEMENT

Should manufacturing/service firms become more environmentally friendly? If this question were posed to the general public, it is likely that the answer would be a resounding “Yes”. However, from the perspective of entrepreneurs, managers and executives, the decision to undertake green/environmentally friendly programs or initiatives is not easy. A number of variables, processes and business dynamics need to be considered. This is because there are Benefits, Opportunities, Costs and Risks associated with the implementation of these types of programs. Our investigation presents a theoretical model that can assist managers when they face a situation in which a decision has to be made with respect to the potential implementation of a green initiative. We hope that our proposed framework will contribute to a better understanding of the dynamics behind the decision to implement/not implement environmentally friendly programs.
1. Introduction

Our investigation presents a decision-making model that can help firms when they face the decision to implement/not implement green initiatives. Undoubtedly, benefits (B) and/or opportunities (O) can result from these environmentally friendly efforts. However, it is also possible that there are costs (C) and/or risks (R) associated with them. These BOCR can be observed at the operational and strategic levels. Therefore, we posit that the decision to adopt a green initiative on the part of any organization should be the result of a detailed analysis of the variables, processes and dynamics that could potentially be impacted, beneficially or detrimentally, by the implementation of these types of initiatives.

To understand these issues better, we first deal with the literature that addresses the type of relationships that can exist amongst important variables in the operations of a firm (e.g. quality, cost, on-time deliveries). In particular, we focus on the influential investigations by Wickham Skinner and other authors who affirm that there will always be “trade-offs” between at least one pair of competitive characteristics in the operations of a firm and its product(s) or service(s). In the context of our investigation, this means that adopting a green initiative (e.g. a more environmentally friendly raw material), with all its implied benefits, can also potentially have a negative effect on at least one different operational aspect (e.g. a decrease in production quality).

It is important to acknowledge that the final decision to undertake an environmentally friendly program or initiative can also depend on the risks (e.g. non-compliance with governmental regulations) and/or opportunities (e.g. targeting a market segment that favors green products) associated with it. In other words, the final decision might depend on variables, processes and dynamics that take place at the strategic level, and not necessarily on those that occur at the operational level. These business dynamics can be understood better through an analysis of the influential works of authors (e.g. Christensen & Overdorf, 2000) who have proposed the “disruptive change” and associated concepts, and also by examining Porter and van der Linde’s (1995a, 1995b) investigations.

The preceding paragraphs give us the basis to present a decision-making model that can capture the discussed business variables, dynamics and processes. To construct a framework that integrates the benefits, opportunities, costs and risks (BOCR) relating to the implementation of a green initiative, we utilize the methodology known as the analytic hierarchy process (AHP) proposed by Thomas Saaty (e.g. 1990). While there have been a number of investigations dealing with AHP-BOCR models and environmental issues, a framework that can help managers to decide whether they should implement/not implement a green initiative has not, to the best of our knowledge, been proposed before.

The rest of the paper is organized as follows: Section 2 presents an overview of the literature on trade-offs between pairs of competitive aspects of a firm. It also discusses important concepts that allow us to understand better the adoption/non-adoption of new initiatives. Section 3 deals with the literature on AHP/ANP-BOCR studies and green initiatives. Section 4 provides instructions on how to conceptualize and construct the type of model we are proposing. An illustrative example is presented in Section 5, while a discussion, conclusions and opportunities for future research are included in Section 6.

2. Understanding potential benefits, opportunities, costs and risks associated with the implementation of green initiatives

2.1. Trade-offs amongst competitive aspects of a firm: An overview

In his seminal works, Wickham Skinner (e.g. 1969, 1974, 1992, 1996) states that to be successful, all firms need to prioritize amongst several competitive aspects that define their operations. This prioritization is only the logical consequence of the compromised relationship that, according to him, exists between at least one pair of competitive capabilities (e.g. quality, cost, delivery, flexibility). Put differently, Skinner argues that it is impossible for any firm, and the product(s) or service(s) it offers
to the public, to be “the best at everything”. The origins of these limitations can be fully understood if businesses are viewed as “systems [that] are constrained by available technologies of equipment, processes, materials and management” (Skinner, 1996, p. 6).

Skinner’s trade-offs model has been debated vigorously, especially in the operations management literature. A considerable number of papers have argued for or against the idea of compromised relationships between pairs of competitive aspects. In particular, some of these investigations have attempted to explore, empirically or theoretically, whether achieving higher levels of performance in one competitive dimension (e.g. quality) comes at the expense of lower levels of performance in another one (e.g. production cost). We now present only a small sample of studies that have dealt with this theory and/or its competing concepts. We classify these investigations based on the utilized approach (empirical or theoretical), and also according to some of their main conclusions:

Avella, Vazquez-Bustelo, and Fernandez (2011) (empirical, “trade-offs can be avoided altogether”); Boyer and Lewis (2002) (empirical, “trade-offs remain”); Cai and Yang (2014) (empirical, “partial support for the trade-offs concept”); Collins, Cordon, and Julien (1998) (empirical, “no support for the trade-offs model”); Corbett and Claridge (2002) (empirical, “results generally consistent with the trade-offs model”); Corbett and Whybark (2001) (empirical, “evidence consistent with the sand cone model”); Dabhilkar (2011) (empirical, “evidence in favor of the trade-off model”); da Silveira (2005) (empirical, “trade-offs can be improved”); Da Silveira and Slack (2001) (empirical, “trade-offs are real and dynamic”); Ferdows and De Meyer (1990) (empirical, “trade-offs can be avoided altogether”); Filippini, Forza, and Vinelli (1998) (empirical, “impossible to conclude that there are no trade-offs”); Flynn and Flynn (2004) (empirical, “there is some evidence of trade-offs”); New (1992) (theoretical, “trade-offs do exist”); Noble (1995) (empirical, “firms can no longer compete on the basis of one or two capabilities”); Rosenzweig and Easton (2010) (empirical, “found no support for the classical trade-offs model”); Rosenzweig and Roth (2004) (empirical, “the trade-offs model has been superseded”); Sarmiento (2010, 2011, 2013); Sarmiento and Shukla (2011); Sarmiento, Sarkis, and Byrne (2010); Sarmiento, Shukla, and Izar-Landeta (2013) (theoretical, “there is a need for a better understanding of the trade-offs model”); Schmenner and Swink (1998) (theoretical, “the trade-offs and cumulative capabilities models are not rival concepts”); Schroeder, Shah, and Xiaosong Peng (2011) (empirical, “trade-offs are appropriate when operating at or near the efficient frontier”); Singh, Wiengarten, Nand, and Betts (2015) (empirical, “the trade-offs model is not used”); Swink, Talluri, and Pandejpong (2006) (empirical, “trade-offs among NPD performance outcomes are manifested more strongly in highly efficient projects when compared to inefficient projects”).

These and other papers have continued the discussion as to whether trade-offs between pairs of competitive capabilities do exist. The trade-offs debate is relevant to the topic of implementing green initiatives. This is because it is entirely possible that just as there are beneficial effects of adopting environmentally friendly programs, there are also detrimental impacts. More specifically, it is important to investigate whether implementing a green initiative (i.e. augmenting a firm’s “green performance”) results in diminishing levels of performance in another metric (e.g. production cost). And this potential trade-off situation, we think, could influence the decision of whether a given green initiative should/should not be implemented by an organization.

A recent line of research developed by Sarmiento and colleagues (e.g. Sarmiento, 2011, 2013; Sarmiento, Thurer, & Whelan, 2016; Sarmiento et al., 2013) has identified a series of problems with the way past investigations have understood, characterized and tested Skinner’s model. For the purpose of this paper, we focus on two particular aspects of their investigations: (1) contrary to what other researchers have claimed (e.g. Rosenzweig & Easton, 2010; Singh et al., 2015), there is evidence of trade-offs between at least one pair of competitive aspects in the operations of firms and their resulting products (Sarmiento et al., 2016); and, (2) evidence of trade-offs can be identified using individual units of analysis (Sarmiento, 2011; Sarmiento et al., 2016). This means that
individual systems (e.g. a manufacturing firm) or individual products/services (e.g. an automobile) can be used to determine whether trade-offs between pairs of competitive dimensions do exist.

In summary, our investigation makes a valuable contribution to the trade-offs literature because, to the best of our knowledge, no previous research has analyzed the implications that Skinner’s model has for the topic of green initiatives using the approach we are presenting.

2.2. Variables, processes and dynamics that explain the adoption/non-adoption of new initiatives

Disruptive change and its related concepts (e.g. disruptive technologies, disruptive innovation) have received much attention over the past couple of decades. Influential papers and books (e.g. Bower & Christensen, 1995; Christensen & Overdorf, 2000; Christensen & Raynor, 2003) have generated fruitful discussions that have moved forward our understanding of those topics. While the debate about their potential value as legitimate and useful management theories continues (see for example Yu & Hang, 2010 for an analysis of the relevant literature), in this paper we concentrate on the way those authors explain the variables, dynamics and processes that determine whether a firm is capable (or willing) of adopting a new strategy, initiative or program. We think that their works can be a useful framework to understand the reasons that can lead firms to implement/not implement green initiatives. We now offer a detailed analysis of some of the concepts that are relevant to our investigation.

In their influential article, Christensen and Overdorf (2000, p. 2) discuss the variables and dynamics that explain “…what an organization can and cannot do”. In their view, an organization’s capabilities (i.e. “resources”, “processes” and “values”) dictate, to a large extent, “…what sorts of innovations [an] organization will be able to embrace…”. “Resources” in an organization, they say, include “…equipment, technologies, and cash…”, but also “…product designs, information, brands, and relationships with suppliers, distributors, and customers”. They define “(P)rocesses” as “…the patterns of interaction, coordination, communication, and decision-making employees use to transform resources into products and services of greater worth”. Christensen and Overdorf (2000, p. 2) continue by stating that an organization’s “(V)alues” are:

... the standards by which employees set priorities that enable them to judge whether an order is attractive or unattractive, whether a customer is more important or less important, whether an idea for a new product is attractive or marginal, and so on.

More specifically, Christensen and Overdorf (2000) argue that these values define what an organization is capable of doing, because those values are/should be consistent with its cost structure or its business model. Therefore, for a business to prosper, its employees must prioritize decisions, at every level, that are in line with the company’s values. Christensen and Overdorf (2000, p. 3) further decompose these “values” into two sets: the first one relates to “…the way the company judges acceptable gross margins”, and the second one to “…how big a business opportunity has to be before it can be interesting”.

We opine that Christensen and Overdorf’s (2000) investigation is a cogent analysis of the variables, processes and dynamics that are behind a firm’s decision to adopt a new technology/initiative/program (green or otherwise). In particular, we identify the first set of values in Christensen and Overdorf’s (2000) framework as those that have a direct bearing on the short term/current operations of a firm (e.g. “benefits” and “costs”). To support our words, we quote Christensen and Overdorf (2000, p. 3) again:

If, for example, a company’s overhead costs require it to achieve gross profit margins of 40%, then a value or decision rule will have evolved that encourages middle managers to kill ideas that promise gross margins below 40%. Such an organization would be incapable of commercializing projects targeting low-margin markets—such as those in e-commerce—even though another organization’s values, driven by a very different cost structure, might facilitate the success of the same project.
Similarly, we posit that the second set of values in Christensen and Overdorf’s (2000) framework describe the rationale by which a firm can come to the conclusion that a business opportunity is worth pursuing. We understand a business opportunity as something that could yield positive/good results, but is not guaranteed to do so. Therefore, we think that Christensen and Overdorf’s (2000) second set of values have to do with the “opportunities” and “risks” that are associated with any new initiative/program undertaken by firms.

Our understanding of Christensen and Overdorf’s (2000) framework as describing potential benefits/costs and opportunities/risks that all firms can face is consistent with the way Saaty and Vargas (2006, p. 13) conceptualize these same variables (our italics, their bold):

The favorable sure concerns are called benefits while the unfavorable ones are called costs. The uncertain concerns of a decision are the positive opportunities that the decision might create and the negative risks that it can entail.

Adding to the aspects that determine the adoption of new initiatives, it is important to note that external agents/factors can also influence these types of decisions. For example, in their much-cited works, Porter and van der Linde (1995a, 1995b) openly advocate for properly designed environmental regulations that, in their view, can “… trigger innovation that may partially or more than fully offset the costs of complying with them” (1995b, p. 98). Notice that Porter and van der Linde do acknowledge the (at least initial) “downside” of regulations that might force firms to become more environmentally friendly in their operations. Whether these influential scholars were correct in their prediction is debatable (see Ambec, Cohen, Elgie, & Lanoie, 2013, for a discussion on what is known as the “Porter hypothesis”). Nevertheless, their works serve as a reminder that in some cases, businesses might be forced/encouraged to adopt green initiatives by external factors, even if these innovations might have an initial negative effect on the business model and/or operations of the firm.

2.3. Discussion

This section has dealt with some important aspects that need to be accounted for when firms contemplate the implementation of a green initiative. Since all firms have (or should have) a business model in place, it is likely that adopting a green initiative, with its immediate environmental and (possibly) other benefits, can also have a detrimental effect, at least initially, on one or more important metrics that define their operations (e.g. quality, cost, delivery). This is consistent with Skinner’s idea that a trade-off relationship between at least one pair of competitive aspects will always exist. It is also in line with Christensen and Overdorf’s contention that there are limits as to what innovations an organization will be able to embrace, because such innovations (e.g. implementing a green initiative) have to be evaluated vis-à-vis a firm’s cost structure or business model. Arguably, these variables, processes and dynamics represent the “benefits” and “costs” associated with the adoption of a green initiative.

On the other hand, Christensen and Overdorf also affirm that when a new business opportunity is big/attractive enough, it can prompt a firm to go beyond its established business model or cost structure in order to adopt/implement an innovation. Nonetheless, as Porter and van der Linde point out, adopting a new initiative/program is not always the result of a new business opportunity pursued expressly by a firm. External/strategic factors (e.g. government regulations, requirements from suppliers or customers) might intervene in the decision of firms to undertake, for example, environmental initiatives. In our view, these variables, processes and dynamics can be understood as potential “opportunities” and “risks” associated with the implementation of a green initiative.

In the light of the current discussion, we think that the decision to implement a green initiative can be characterized as a process that has to consider the potential benefits and costs (e.g. immediate sure impacts on the business model/metrics of a firm), as well as the potential opportunities and risks (e.g. non-compliance with a new environmental regulation) associated with it. Put simply, if adopting green technologies/initiatives did not involve costs and/or risks, and only yielded benefits...
and/or good opportunities, the decision to implement them would not be difficult. Yet, there is evidence that adopting new technologies or directives (for example, green initiatives/directives) is not easy (see for example Crotty & Smith, 2006, for a study on the apparent difficulties associated with new environmental regulations and their effects on the operations of Automotive firms in the UK).

We have characterized the decision to undertake a green initiative/program as a process involving benefits, opportunities, costs and risks. Therefore, it is possible to model it using an AHP-BOCR approach. The next section discusses previous investigations that have taken a similar approach.

3. AHP/ANP-BOCR studies and green initiatives: a review

The AHP and its generalization, the analytic network process (ANP) have been used extensively to investigate a great variety of topics pertaining to green/environmental issues. Our investigation focuses on the potential BOCR associated with the implementation/no implementation of a green initiative in a business. The AHP-BOCR model presented in our paper is similar to the one proposed by Saaty (2002, 2004, 2013). He constructed an AHP hierarchy with the objective of providing guidance in problems when decision makers are presented with a binary choice: “Yes” or “No”. In our proposed model, these two alternatives are the only potential answers to a question that businesses often have to face these days: “should my firm adopt this green initiative?” With this as a background, in this section we first offer some general examples of AHP/ANP applications dealing with green/environmental topics. We will then focus on AHP/ANP-BOCR investigations that have dealt with similar themes.

3.1. AHP/ANP investigations dealing with green/environmental topics

AHP/ANP have been utilized to investigate subjects such as “green suppliers” (e.g. Büyüközkan & Çifçi, 2012; Li, Zhou, & Yang, 2012; Lu, Wu, & Kuo, 2007; Noci, 1997; Peng, 2012); “waste management” (e.g. Brent, Rogers, Ramabitsa-Siimane, & Rohwer, 2007; Contreras, Hanaki, Aramaki, & Connors, 2008; Karamouz, Zahraie, Kerachian, Jaafarzadeh, & Mahjouri, 2007; Pires, Chang, & Martinho, 2011; Wang, Qin, Li, & Chen, 2009); “green manufacturing” (e.g. Chuang & Yang, 2014; Govindan, Diabat, & Shankar, 2015; Gupta, Dangayach, Singh, & Rao, 2015; Sangwan, 2011); “green product design” (e.g. Chan, Wang, White, & Yip, 2013; Guo, Zhou, Li, & Xie, 2015; Kuo, Chang, & Huang, 2006), amongst other topics. While these investigations offer useful insights into a number of green/environmental issues, the AHP/ANP models utilized do not include a BOCR approach.

3.2. AHP/ANP - BOCR investigations dealing with green/environmental themes

We now move on to previous studies that have utilized a BOCR approach to examine our topics of interest. We searched for investigations in several databases using combinations containing the keyword “BOCR” and one of the following terms: “green manufacturing”, “green supply”, “green initiative”, “green operations”, “green design”, “green product” and “green production”. These terms were chosen because we considered that the central themes in our investigation could be found using any of the proposed keyword combinations. The different searches resulted in over eighty documents, and we proceeded to analyze them in detail. The following studies were selected on the basis that the topics/models included in them were relevant for our investigation: (Azizi & Ray, 2015; Costantino, De Minicis, & Di Gravio, 2008; De Felice, Petrillo, & Cooper, 2012; Hsueh & Lin, 2015; Palanisamy & Abdul Zubar, 2013; Sakri & Ebrahimnejad, 2015; Sarkis, Meade, & Presley, 2012; Shih, Cheng, Chen, & Lin, 2014; Shieue & Lin, 2012; Tuzkaya, Önüt, Tuzkaya, & Gülsün, 2008; Xia, Yu, Gao, & Cheng, 2017).

The analyzed investigations present valuable information and results vis-à-vis different topics and AHP/ANP - BOCR models. However, none of them proposed a hierarchical model with which a question similar to “should my firm adopt a green initiative?” can be answered. Therefore, we can say that to the best of our knowledge, the AHP-BOCR model in our investigation has not been proposed in previous studies.
4. How to construct our proposed AHP-BOCR model

Before we proceed to explain how our framework should be built, we offer a brief description of the general structure of an AHP model. Saaty (2002) writes that the AHP is a decision hierarchy that includes a goal, criteria and alternatives. The criteria are then pairwise-compared for their importance relative to the main goal, while the alternatives are pairwise-compared with respect to each criterion. These comparisons result in scales of relative importance/performance. The relative scales are then synthesized through a process of weighting and adding from which the best alternative/course of action will be identified. When making the pairwise comparisons, both subjective judgment and objective data can be utilized.

The following table shows the fundamental scale recommended for the pairwise comparisons (Table 1).

When structuring an AHP-BOCR model, the same general instructions explained before have to be followed. However, a BOCR model requires the construction of up to four different hierarchies, one for each those categories. We now lay out the different steps involved in the development of our model.

Step 1: establish the goal/objective/research question: since our objective is to investigate whether firms should adopt a given green initiative, a question similar to “should my firm/business implement/adopt ‘X’ green program/initiative?” can serve as a guide for the whole investigation.

Step 2: define the criteria and sub-criteria for each of the BOCR hierarchies.

2.1. Benefits: apart from the evident environmental benefits of adopting these types of programs, other positive outcomes should be included in this hierarchy. For example, it could be possible that implementing “X” green initiative could also have a beneficial impact on a different operational aspect (e.g. “the results of the pilot study indicate that the quality of my product can be increased by the implementation of ‘X’ green initiative”).

| Intensity of importance | Definition                     | Explanation                                      |
|-------------------------|-------------------------------|-------------------------------------------------|
| 1                       | Equal importance              | Two activities contribute equally to the objective |
| 2                       | Weak                          |                                                 |
| 3                       | Moderate importance           | Experience and judgment slightly favor one activity over another |
| 4                       | Moderate plus                 |                                                 |
| 5                       | Strong importance             | Experience and judgment strongly favor one activity over another |
| 6                       | Strong plus                   |                                                 |
| 7                       | Very strong or demonstrated importance | An activity is favored very strongly over another, its dominance is demonstrated in practice |
| 8                       | Very, very strong             | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 9                       | Extreme importance            |                                                 |
| Reciprocals of above    | If activity i has one of the above nonzero numbers assigned to it when compared to activity j, then j has the reciprocal value when compared with i | A reasonable assumption |

Source: Table 2 in Saaty (2002).
2.2. Opportunities: these contemplate all potential opportunities that might arise from the adoption of these types of initiatives (e.g. “implementing X green initiative could help us to attract new customers”).

2.3. Costs: here we include all negative, undesirable and immediate outcomes associated with the implementation of green programs (e.g. “the implementation of X green initiative can increase our operational costs”; “the results of the pilot study show that the implementation of X green program can deteriorate the quality of our products”).

2.4. Risks: these include all potential negative aspects associated with these environmental programs (e.g. “if we do not implement X green initiative, we risk government sanctions”).

Step 3: define the alternative/solutions: in our model, a simple binary choice is presented: “YES, our firm should implement X green initiative”, or, “NO, our firm should not implement X green initiative”.

A pilot study and/or expert opinions can be used in order to establish the immediate positive and negative (benefits and costs) impacts on the operational variables of a firm. For example, once a favorable impact has been identified, the analyst should then establish, quantitatively or qualitatively, its magnitude. Let us suppose that implementing a green initiative also has a positive impact on “quality”. Let us also suppose that the magnitude of this impact is very high. Given that the potential solutions for this problem are “Yes, implement” and “No, do not implement” the comparison ratio between these two alternatives could be (utilizing the scale recommended by Saaty) “9/1” or “7/1”.

The same analysis should be done when considering the unfavorable aspects of adopting a green initiative. Once a detrimental effect has been detected, for example, on a different operational variable (e.g. production cost), this should be quantified. Let us suppose that implementing a green initiative carries with it an increase in “production cost”. Let us also suppose that this increase is not too high. Considering the two potential solutions for the problem ("Yes" and “No”), the comparison ratio could be “3/1” or “4/1”. The same rationale should be followed when assessing the potential opportunities and risks.

5. An illustrative example
In this section, we offer a simulated example of our proposed framework. This will help us to illustrate how the relevant variables, processes and dynamics pertaining to the implementation of a green initiative can be understood, conceptualized and integrated into a model that can be utilized by students, researchers, and practitioners/decision-makers. We now detail the different aspects of our illustrative case:

Objective/research question: “Should our firm implement X green initiative?”

Benefits: for illustrative purposes, here we only consider two criteria: “environmental (E)” and “operational (O)”. The former includes two sub-criteria: “less air pollution (LAP)” and “less soil pollution (LSP)”. On the other hand, “higher production quality (HPQ)” and “more rapid manufacturing process (MRMP)” are modeled as operational sub-criteria.

Opportunities: this hierarchy contemplates two main criteria: “opportunities with national customers (ONC)” and “opportunities with overseas customers (OOC)”. No sub-criteria were included.
Costs: here we include two criteria: “higher manufacturing costs (HMC)” and “decreased flexibility in production processes (DFPP)”. No sub-criteria were considered. Here we note again that this hierarchy does not only include financial costs. Undesirable impacts on operational, non-financial variables such as DFPP are also contemplated.

Risks: in our illustrative example, this hierarchy was not included.

Alternatives/solutions: (1) “Yes, implement ‘X’ green initiative”; (2) “No, do not implement ‘X’ green initiative”.

Figures 1–3 illustrate the three different hierarchies described above:
Simulated numerical comparisons are now presented. They will allow us to explain the utility of our model. Tables 2–4 show these illustrative results:

We now make calculations in order to explore whether it is convenient for the hypothetical firm to undertake “X” green initiative. First of all, we will obtain an initial result based exclusively on the immediate impacts of implementing “X” green initiative. In other words, we will calculate a preliminary result on the basis of the beneficial and detrimental impacts that implementing “X” has on the operational variables included in our example. Consistent with Saaty (2002, 2004, 2013), we divide the numerical information contained in the “Global Priorities” matrix of the “Benefits” hierarchy (Table 2) by the corresponding information in the “Costs” hierarchy (Table 4) for each of the two alternatives (YES, NO), with the highest ratio indicating the preferred alternative:

\[
\frac{\text{Benefits}}{\text{Costs}} \quad \text{YES} = \frac{0.742}{0.861} = 0.861 \\
\text{NO} = \frac{0.258}{0.139} = 1.856
\]

This result tells us that if we only take into account the immediate beneficial and detrimental impacts that implementing “X” has on a number of operational aspects in the hypothetical firm, the most convenient course of action would be to not implement the green initiative.

While it is possible that some real-life firms might base their decisions only on immediate impacts/results, it is also likely that others might contemplate some strategic aspects (e.g. new business opportunities) before making an important decision. To illustrate this scenario, we now obtain a second result that includes the “Opportunities” information for each of the two alternatives:

\[
\frac{\text{Benefits} \times \text{Opportunities}}{\text{Costs}} \quad \text{YES} = \frac{0.742 \times 0.872}{0.861} = 0.751 \\
\text{NO} = \frac{0.258 \times 0.128}{0.139} = 0.237
\]

This second calculation shows that when the potential opportunities of adopting “X” green initiative are also considered, the initial decision is reversed. This means that the best alternative for the simulated firm would be to implement the green initiative.
Table 2. Simulated numerical comparisons of the “Benefits” hierarchy

| Global priorities |  |  |  |
|-------------------|------------------|------------------|------------------|
| Alternatives      | YES              | NO               |
| Priority          | 0.742            | 0.258            |

Matrix: Main

| Environmental | Operational | Priority |
|---------------|-------------|----------|
| Environmental | 1           | 3        | 0.75    |
| Operational   | 0.333       | 1        | 0.25    |
| Consistency ratio | 0        |          |         |

Matrix: Environmental: LAP (Alternatives)

| Yes | No | Priority |
|-----|----|----------|
| Yes | 1  | 3        | 0.75    |
| No  | 0.333 | 1    | 0.25    |
| Consistency ratio: | 0      |

Matrix: Environmental: LSP (Alternatives)

| Yes | No | Priority |
|-----|----|----------|
| Yes | 1  | 2        | 0.667   |
| No  | 0.5 | 1      | 0.333   |
| Consistency ratio: | 0      |

Matrix: Operational: HPQ (Alternatives)

| Yes | No | Priority |
|-----|----|----------|
| Yes | 1  | 4        | 0.8     |
| No  | 0.25 | 1      | 0.2     |
| Consistency ratio: | 0      |

Matrix: Operational: M RPM (Alternatives)

| Yes | No | Priority |
|-----|----|----------|
| Yes | 1  | 2        | 0.667   |
| No  | 0.5 | 1      | 0.333   |
| Consistency ratio: | 0      |

Notes: LAP = less air pollution. LSP = less soil pollution. HPQ = higher production quality. RPM = more rapid manufacturing process.
| Global priorities | Alternatives | Priority |
|-------------------|--------------|----------|
| Yes               | 0.872        |          |
| No                | 0.128        |          |

**Matrix: Main**

|          | O N C | O O C | Priority |
|----------|-------|-------|----------|
| O N C    | 1     | 0.2   | 0.167    |
| O O C    | 5     | 1     | 0.833    |

Consistency ratio 0

**Matrix: Main: O N C (Alternatives)**

|          | Yes | No | Priority |
|----------|-----|----|----------|
| Yes      | 1   | 6  | 0.857    |
| No       | 0.167 | 1 | 0.143    |

Consistency ratio 0

**Matrix: Main: O O C (Alternatives)**

|          | Yes | No | Priority |
|----------|-----|----|----------|
| Yes      | 1   | 7  | 0.875    |
| No       | 0.143 | 1 | 0.125    |

Consistency ratio 0

Notes: O N C = opportunities with national customers. O O C = opportunities with overseas customers.

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**Table 4. Simulated numerical comparisons of the “Costs” hierarchy**

| Global priorities | Alternatives | Priority |
|-------------------|--------------|----------|
| Yes               | 0.861        |          |
| No                | 0.139        |          |

**Matrix: Main**

|          | H M C | D F P P | Priority |
|----------|-------|---------|----------|
| H M C    | 1     | 7       | 0.875    |
| D F P P  | 0.143 | 1       | 0.125    |

Consistency ratio 0

**Matrix: Main: H M C (Alternatives)**

|          | Yes | No | Priority |
|----------|-----|----|----------|
| Yes      | 1   | 8  | 0.889    |
| No       | 0.125 | 1 | 0.111    |

Consistency ratio 0

**Matrix: Main: D F P P (Alternatives)**

|          | Yes | No | Priority |
|----------|-----|----|----------|
| Yes      | 1   | 2  | 0.667    |
| No       | 0.5 | 1  | 0.333    |

Consistency ratio 0

Notes: H M C = higher manufacturing cost. D F P P = decreased flexibility in production process.
6. Discussion, conclusions, and opportunities for future research

Although the results in Section 5 are hypothetical, they are useful because we think they are not too dissimilar from the phenomena that take place in real-world settings. It is unrealistic to only expect immediate benefits and/or good (business or otherwise) opportunities from the implementation of green initiatives. Detrimental immediate effects and/or risks should also be anticipated. These undesirable immediate effects (e.g., increased production costs) are consistent with the investigations by operations management theorists such as Skinner (1992) who affirms that to get more of “x” (e.g., environmental benefits), one has to have less of “y” (e.g., reduced flexibility in production process). These dynamics are also in line with the works by Christensen and Overdorf (2000) who say that there are limits as to what innovations (e.g., implementation of a green initiative) a firm will be able to embrace, because these innovations have to be evaluated vis-à-vis its cost structure or business model. The initial result in Section 5 is a good example of this scenario: When only the immediate benefits and detrimental effects are considered, the best course of action for the hypothetical firm is to not implement the green initiative. This can be explained as follows: although there are immediate environmental and operational benefits to the implementation of a green initiative, the detrimental effects on the firm’s cost structure/business model (as represented by the variables “higher manufacturing costs” and “decreased flexibility in production process”) are so high that the best initial decision is to not pursue the implementation of a green initiative.

The second result in our simulated example allows us to explore another interesting situation. It is possible that when new business opportunities are taken into account, firms might feel encouraged to undertake new initiatives, in spite of the initial detrimental impacts to their operations. This scenario is consistent with the works by Christensen and Overdorf (2000). Their proposed second set of “values” state that sometimes a new business opportunity could be so attractive that it might prompt a firm to go beyond its current cost structure/business model in order to pursue it.

In Section 2 we discussed the possibility that other variables might determine whether a firm should adopt a green initiative. For example, Porter and van der Linde (1995b, p. 98) think that properly designed environmental regulations can “… trigger innovation that may partially or more than fully offset the costs of complying with them”. This means that sometimes firms might be forced to undertake green initiatives/programs in order to comply with environmental regulations, regardless of the (at least initial) detrimental impacts to their operations/business model/cost structure. The pressures to become more environmentally friendly might also come from suppliers and/or customers. These and other types of risks can take place in a real-life setting.

The variables, processes and dynamics involved in the potential implementation of green initiatives are complex. Our investigation has attempted to provide clarity and contribute to a better understanding of these phenomena. In particular, we show how these variables, processes and dynamics can be understood, conceptualized and integrated into a model that can be utilized by students, researchers and practitioners when a decision has to be made on whether a green initiative should be implemented. The next step is to validate our proposed model in a real-world setting. Although our initial recommendation is to utilize this model to investigate the implementation of green initiatives, it is possible that it could also be used to analyze the implementation of other types of initiatives/programs. Also, in the simulated example, we only utilized a limited set of operational and environmental variables. Other such important aspects, as well as different types of opportunities and/or risks, should be considered in future studies.

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Sarmiento & Vargas-Berrones, Cogent Engineering (2018), 5: 1432120
https://doi.org/10.1080/23311916.2018.1432120

9(8), 878–899. https://doi.org/10.1080/17517575.2013.879214
Gupta, S., Daneyach, G. S., Singh, A. K., & Rao, P. N. (2015). Analytic hierarchy process (AHP) model for evaluating sustainable manufacturing practices in Indian electrical panel industries. Procedia-Social and Behavioral Sciences, 189, 208–216. https://doi.org/10.1016/j.pssb.2015.03.216
Hsueh, J. T., & Lin, C. Y. (2015). Constructing a network model to rank the optimal strategy for implementing the sorting process in reverse logistics: Case study of photovoltaic industry. Clean Technologies and Environmental Policy, 17(1), 155–174. https://doi.org/10.1007/s10098-014-0770-3
Karamouz, M., Zohraie, B., Kerachian, R., Jafarzadeh, N., & Mahjouri, N. (2007). Developing a master plan for hospital solid waste management: A case study. Waste Management, 27(5), 626–638. https://doi.org/10.1016/j.wasman.2006.03.018
Kuo, T. C., Chang, S. H., & Huang, S. H. (2006). Environmentally conscious design by using fuzzy multi-attribute decision-making. The International Journal of Advanced Manufacturing Technology, 29(5), 419–425. https://doi.org/10.1007/s00170-005-2540-1
Li, D. G., Zhou, Z. Y., & Yang, C. (2012). A model on supplier selection in green supply chain based on BP neural network. Applied Mechanics and Materials, 143–144, 312–316. https://doi.org/10.4028/www.scientific.net/AMM.204-208
Lu, L. Y., Wu, C. H., & Kuo, T. C. (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. International Journal of Production Research, 45(18–19), 4317–4331. https://doi.org/10.1080/00207540701472694
New, C. (1992). World-class manufacturing versus strategic trade-offs. International Journal of Operations & Production Management, 12(4), 19–31. https://doi.org/10.1108/EUM00000000001298
Noble, M. A. (1995). Manufacturing strategy: Testing the cumulative model in a multiple country context. Decision Sciences, 26(5), 693–721. https://doi.org/10.1111/j.1540-5915.1995.tb01866.x
Noci, G. (1997). Designing “green” vendor rating systems for the assessment of a supplier’s environmental performance. European Journal of Purchasing & Supply Management, 3(2), 103–114. https://doi.org/10.1016/S1938-6270(97)00012-0
Polanček, P., & Abdul Zubair, H. (2013). Hybrid MCDM approach for vendor ranking. Journal of Manufacturing Technology Management, 24(6), 905–928. https://doi.org/10.1108/JMTM-02-2012-0015
Peng, J. (2012). Research on the optimization of green suppliers based on AHP and GRA. Journal of Information & Computational Science, 9(1), 173–182.
https://doi.org/10.1111/j.1540-5915.1995.tb01866.x
Pires, A., Chang, N. B., & Martins, G. (2011). An AHP-based fuzzy interval TOPSIS assessment for sustainable expansion of the solid waste management system in Setúbal Peninsula, Portugal. Resources, Conservation and Recycling, 56(1), 7–21. https://doi.org/10.1016/j.resconrec.2011.08.004
Porter, M. E., & Van der Linde, C. (1995a). Green and competitive: Ending the stalemate. Harvard Business Review, 73(5), 120–134.
Porter, M. E., & Van der Linde, C. (1995b). Toward a new conception of the environment-competitiveness relationship. The Journal of Economic Perspectives, 9(4), 97–118. https://doi.org/10.1257/jep.9.4.97
Rosenzweig, E. D., & Easton, G. S. (2010). Tradeoffs in manufacturing? A meta-analysis and critique of the literature. Production and Operations Management, 19(2), 127–141. https://doi.org/10.1111/j.oms.2010.19.issue-2
Rosenzweig, E. D., & Roth, A. V. (2004). Towards a theory of competitive progression: Evidence from high-tech manufacturing. Production and Operations Management, 13(4), 354–368.
Saatci, T. L. (1990). How to make a decision: The analytic hierarchy process. European Journal of Operational Research, 48(1), 9–26. https://doi.org/10.1016/0377-2217(90)90057-I
Saaty, T. L. (2002). Decision making with the analytic hierarchy process. Scientia Iranica, 9(3), 215–229.
Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes (AHP/ANP). Journal of Systems Science and Systems Engineering, 13(1), 1–35. https://doi.org/10.1007/s11518-006-0151-5
Saaty, T. L. (2013). Theory and applications of the analytic network process: Decision making with benefits, opportunities, costs, and risks. Pittsburgh, PA: RWS Publications.
Saaty, T. L., & Vargas, L. G. (2006). Decision making with the analytic network process: Economic, political, social and technological applications with benefits, opportunities, costs and risks. New York, NY: Springer Science + Business Media.
Saki, P., & Ebrahiminejad, S. (2015). An integrated approach for measuring the performance of suppliers in the pharmaceutical industry: A case study. International Journal of Logistics Systems and Management, 22(3), 267–295. https://doi.org/10.1504/IJLSM.2015.072283
Sangwan, K. S. (2011). Development of a multi criteria decision model for justification of green manufacturing systems. International Journal of Green Economics, 5(3), 285–305. https://doi.org/10.1504/IJGE.2011.044439
Sarkis, J., Meade, L. M., & Presley, A. R. (2012). Incorporating sustainability into contractor evaluation and team formation in the built environment. Journal of Cleaner Production, 31, 60–63. https://doi.org/10.1016/j.jclepro.2012.02.029
Sarmiento, R. (2010). Issues with the modelling of manufacturing performance: The trade-offs: Cumulative capabilities paradox. Journal of Modelling in Management, 5(3), 263–274. https://doi.org/10.1108/17465651011092632
Sarmiento, R. (2011). A note on “trade-off and compatibility between performance: Definitions and empirical evidence”. International Journal of Production Research, 49(13), 4175–4183. https://doi.org/10.1080/00207543.2011.978483
Sarmiento, R., & Shukla, V. (2011). Zero-sum and frontier trade-offs: An investigation on compromises and compatibilities amongst manufacturing capabilities. International Journal of Production Research, 49(7–8), 2001–2017. https://doi.org/10.1080/00207543.2013.817519
Sarmiento, R., Sarkis, J., & Byrne, M. (2010). Manufacturing capabilities and performance: A critical analysis and review. International Journal of Production Research, 48(5), 1267–1286. https://doi.org/10.1080/00207540802075343.2010.842558
Sarmiento, R., & Shukla, V. (2013). Natural laws and strategic trade-offs: Implications for research and policy advising. International Journal of Production Research, 51(19), 5934–5945. https://doi.org/10.1080/00207543.2013.817519
Sarmiento, R., Sarkis, J., & Byrne, M. (2010). Manufacturing capabilities and performance: A critical analysis and review. International Journal of Production Research, 48(5), 1267–1286. https://doi.org/10.1080/00207543.2013.817519
Sarmiento, R., & Shukla, V. (2011). Zero-sum and frontier trade-offs: An investigation on compromises and compatibilities amongst manufacturing capabilities. International Journal of Production Research, 49(7–8), 2001–2017. https://doi.org/10.1080/00207540802075343.2010.842558
Sarmiento, R., Shukla, V., & Iázar-Landeta, J. M. (2013). Performance improvements seen through the lens of strategic trade-offs. International Journal of Production Research, 51(15), 4682–4694. https://doi.org/10.1080/00207543.2013.784417
Sarmiento, R., Thurer, M., & Whelan, G. (2016). Rethinking Skinner’s model: Strategic trade-offs in products and services. Management Research Review, 39(10), 1199–1213. https://doi.org/10.1108/MRR-02-2015-0042
Schmenner, R. W., & Swink, M. L. (1998). On theory in operations management. *Journal of Operations Management, 17*(1), 97–113. https://doi.org/10.1016/S0272-6963(98)00028-X

Schooder, R. G., Shah, R., & Xiaosong Peng, D. (2011). The cumulative capability “sand cone” model revisited: A new perspective for manufacturing strategy. *International Journal of Production Research, 49*(16), 4879–4901. https://doi.org/10.1080/00207543.2010.509116

Shih, H. S., Cheng, C. B., Chen, C. C., & Lin, Y. C. (2016). Environmental impact on the vendor selection problem in electronics firms—A systematic analytic network process with BOCR. *International Journal of the Analytic Hierarchy Process, 6*(2), 202–227.

Shiu, Y. C., & Lin, C. Y. (2012). Applying analytic network process to evaluate the optimal recycling strategy in upstream of solar energy industry. *Energy and Buildings, 54*, 266–277. https://doi.org/10.1016/j.enbuild.2012.07.032

Singh, P. J., Wiengarten, F., Nand, A. A., & Betts, T. (2015). Beyond the trade-off and cumulative capabilities models: Alternative models of operations strategy. *International Journal of Production Research, 53*(13), 4001–4020. https://doi.org/10.1080/00207543.2014.983277

Skinner, W. (1969). Manufacturing—missing link in corporate strategy. *Harvard Business Review, 47*(3), 136–145.

Skinner, W. (1996). Manufacturing strategy on the “S” curve. *Production and Operations Management, 5*(1), 3–14.

Skinner, W. (1992). Missing the links in manufacturing strategy. In C. A. Voss (Ed.), *Manufacturing strategy: Process and content* (pp. 13–25). London: Chapman & Hall.

Swink, M., Talluri, S., & Pondejgong, T. (2006). Faster, better, cheaper: A study of NPD project efficiency and performance tradeoffs. *Journal of Operations Management, 24*(5), 542–562. https://doi.org/10.1016/j.jom.2005.09.004

Tuzkaya, G., Önüt, S., Tuzkaya, U. R., & Gulsin, B. (2008). An analytic network process approach for locating undesirable facilities: An example from Istanbul, Turkey. *Journal of Environmental Management, 88*(4), 970–983.

Wang, G., Qin, L., Li, G., & Chen, L. (2009). Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. *Journal of Environmental Management, 90*(8), 2414–2421.

Xia, D., Yu, Q., Gao, Q., & Cheng, G. (2017). Sustainable technology selection decision-making model for enterprise in supply chain: Based on a modified strategic balanced scorecard. *Journal of Cleaner Production, 141*, 1337–1348. https://doi.org/10.1016/j.jclepro.2016.09.083

Yu, D., & Hang, C. C. (2010). A reflective review of disruptive innovation theory. *International Journal of Management Reviews, 12*(4), 435–452. https://doi.org/10.1111/ijmr.2010.12.issue-4

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