Green IT Practices across Industries: A Text-Mining based Analysis

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Abstract

In this paper, we employ a practical perspective and examine the Green IT (GIT) practices across industries using a dictionary-based text mining method. Our research includes two phases: 1) building a GIT dictionary for text mining, and 2) examining GIT practices proliferation in non-IT industries. As the first attempt of using dictionary-based text mining method to study the Green IT practices, this paper has two main implications. First, through building the Green IT dictionary, we provide a broad view of current Green IT practices and present a tool that can be used to examine Green IT practices in future research. Second, while employing a practical perspective, this paper identifies some research gaps which could be addressed in future GIT research.

Keywords

Green IT, practice, dictionary, text mining.

Introduction

Information Technology (IT) plays an important role in corporate sustainability management (Watson, Boudreau & Chen, 2010). The impact of IT is twofold. As a source of problem, design, manufacture, use, and disposal of IT can have direct negative impacts on environmental sustainability, and the global IT industry alone is estimated to account for approximately 2 percent of the global carbon dioxide (CO2) emissions (Gartner, 2007). As a solution, IT is expected to address the 2 percent of emissions by improving its energy efficiency and the remaining 98 percent via innovative applications and to turn the society to be more sustainable (Elliot, 2011; Fuchs, 2008). With the focus on the enabling role of IT, Green IT (GIT) has attracted wide attention from both Information Systems (IS) researchers and practitioners. Previous research has examined GIT from many perspectives, such as concept, benefit, initiation, adoption, and strategies (Brooks, Wang, & Sarker, 2012). While previous research adopted high-level theoretical perspectives (e.g. Melville, 2010; Watson et al. 2010; Jenkin et al. 2011) or theory-informed empirical perspectives on several aspects of GIT (e.g., Bengtsson and Agerfalk, 2011; Butler, 2011a; Chen et al. 2009; Molla, 2009), many overlooked the fact that GIT is an umbrella term that encompasses many IT practices, such as smart grids, building management systems, intelligent transportation systems, teleworking, and videoconferencing (Lee, Park, & Trimi, 2013; Murugesan, 2008; Murugesan & Gangadharan, 2012). We propose that such overlook is due to the lack of practical perspective in GIT research. Indeed, IS field has done relatively little research on understanding green IT practices (Lee, Park, & Trimi, 2013; Melville, 2010; Watson et al., 2010). To balance the academic rigor with practical relevance of GIT research, an integrative practical perspective is required (Jenkin, McShane, & Webster, 2011).

In this paper, we employ a practical perspective and examine the GIT practices across industries using a dictionary-based text mining method. Specifically, the study includes two phases. First, we develop a GIT dictionary that consists of entries (i.e., words and phrases) representing current GIT practices. Second, we analyze the corporate sustainability reports of companies in different industries using the dictionary built...
in the first phase to reveal the current state of GIT practice adoption across industries. This paper has many implications. First, we develop a tool that can be used to examine GIT practices for future research. Second, the cross-industry analysis portrays a bird’s-eye view on the GIT proliferation in different industries, which provides some insights for future GIT research. Third, to the best of our knowledge, this paper is the first attempt in using text mining method to study the GIT-related issue, which shows a potential research opportunity for future GIT research. The rest of the paper is organized as follows. Section two presents a literature review on research in GIT practice and the application of dictionary-based text mining. Section three describes the development of the GIT dictionary. Section four presents the results of analysis of GIT practices across industries. Section five provides a discussion on the results of this paper, and section six presents the conclusion of this paper.

**Literature Review**

**Green IT Practice**

In the IS field, a few of research has examined GIT practice (see Table 1). Two patterns can be found in Table 1. First, in previous research, GIT practice has been conceptualized with wider or narrower scopes and from various perspectives, such as sustainability issues (e.g., energy efficiency, renewable energy, and waste & recycling), technological applications (e.g., data center, hardware, and software,), and GIT functions (e.g., collaboration, pollution prevention, and awareness practices). Second, three primary sources for identifying GIT practices are research papers, practitioner literature (e.g., technical reports, magazines, and organizational documents) and interviews with the relevant experts. A further examination of these papers indicates that the major method used to identify the GIT practices is inductive analysis.

<table>
<thead>
<tr>
<th>Source</th>
<th>Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butler (2011b)</td>
<td>Review of research and practitioner literature</td>
<td>• 4 categories: 1) energy efficiency; 2) dematerialisation; 3) waste and recycling; 4) green operations • 17 practices</td>
</tr>
<tr>
<td>Corbett (2010)</td>
<td>Review of practitioner literature</td>
<td>• 4 quadrants: 1) information to support decision making; 2) direct IT assets and infrastructure; 3) collaboration; 4) sustainable products and services • 16 practices</td>
</tr>
<tr>
<td>Ijab, Molla &amp; Cooper (2012)</td>
<td>Case study (interviews and organizational documents)</td>
<td>• 3 categories: 1) GIT for pollution prevention; 2) GIT for product stewardship; 3) GIT for sustainable development • 3 practices recurrently used in Acadia</td>
</tr>
<tr>
<td>Lee, Park, &amp; Trimi (2013)</td>
<td>Review of relevant materials</td>
<td>• 3 categories: 1) greening of IT; 2) greening by IT; 3) GIT for green growth • 16 practices</td>
</tr>
<tr>
<td>Loeser (2013)</td>
<td>Review of research literature</td>
<td>• 3 categories: 1) IT Sourcing; 2) IT operations; 3) IT disposal • 70 practices</td>
</tr>
<tr>
<td>Lunardi, Alves &amp; Salles (2013)</td>
<td>Not specified</td>
<td>• 7 categories: 1) awareness practices; 2) green data center; 3) discharge and recycling; 4) alternative sources of energy; 5) hardware; 6) printing; 7) software • 37 practices</td>
</tr>
<tr>
<td>Sayeed &amp; Gill (2008)</td>
<td>Interviews with industry experts</td>
<td>• 2 categories: 1) data center GIT initiatives; 2) organization-wide GIT initiatives • 22 practices</td>
</tr>
<tr>
<td>Trimi &amp; Park (2013)</td>
<td>Not specified</td>
<td>• 2 categories: 1) greening IT; 2) greening by IT • 14 sub-categories; 26 practices</td>
</tr>
</tbody>
</table>

**Table 1. Previous conceptualization of GIT practice**

There are some limitations in previous research on GIT practice. First, there is a lack of systematic examination on GIT practice. Previous research on GIT practice categorized GIT practice in many ways. As Table 1 shows, almost each research had one specific way to categorize GIT practices, and, because of the
different focuses, each research adopted a specific GIT scope. The scattered conceptualization of GIT is inconvenient for IS researchers to communicate with each other, as well as difficult for IT practitioners to understand GIT. Second, previous research on GIT practice usually ended up with the identification of some GIT practices. We suggest that the determination of GIT practices is only the first step of research on GIT practice. As we discussed at the beginning of this paper, the major challenge of GIT is to address the 98 percent of emissions generated by non-IT industries through innovative GIT applications (Elliot, 2011). Therefore, to examine the GIT practice, one major task is to examine the adoption of GIT practice in non-IT industries. It seems to us that such focus has been overlooked by IS researchers. Thus, in this paper, our aim is to address the two limitations identified. Through building a GIT dictionary, we provide a systematic examination of current popular GIT practices, and through conducting a dictionary-based text mining analysis, we reveal the proliferation of GIT practices across industries.

**Dictionary-based Text Mining**

Dictionary-based text mining is an efficient way to understand the unstructured text, especially in concept identification and text categorization. It allows researchers to systematically identify and assess the concepts addressed in the text. To adopt the dictionary-based text mining method, one needs to first build a dictionary based on the research requirements or find an existing dictionary. Typically, a dictionary contains categories that are described by lists of entries (i.e., words, word stems, or phrases) with shared meanings (Landmann & Zuell, 2008; Weber, 1983). To analyze a text, the entry frequencies and thus category frequencies are counted and, based on these frequencies, the concepts addressed in the text can be determined. Dictionary-based text mining method is increasingly embraced by researchers because of its ability to process large volumes of data at high speed and the limitation of its alternative, i.e., traditional manual content analysis method, in the era of big data (Krippendorff, 2004). Manual content analysis has faced the criticism on coding reliability and potential coding errors caused by coder fatigue, misapplication of coding schema, and potential disagreement between coders on particular attribute values for a long time (Potter & Levine-Donnerstein, 1999; Scott & Smith, 2005; Gill, Dickinson & Scharl, 2008). In addition, with volumes of digitized textual materials on corporate sustainability being increasingly available, manual content analysis has met its methodological bottleneck as to survey the wealth of the materials in a quantifiable, objective, transparent, and time-efficient manner. Compared with manual content analysis, dictionary-based text mining is “consistent (without random human error), replicable (the process is rule-based), scalable (coding efforts are the same regardless of the number of reports analyzed), and transparent (when the keywords/phrases and search criteria used to automate identification are made available)” (Boritz, Hayes & Lim, 2013). The dictionary-based text mining method has been applied in many research areas, such as Tourism Research (Stepchenkova, Kirilenko & Morrison, 2009; Scott & Smith, 2005), Agriculture (Robson & Davis, 2014), Political Science (Stieglitz & Dang-Xuan, 2013; Pennings, 2006), Medical Science (Liu et al., 2006; Asghar et al., 2013), and Psychology (Wilson, 2006). Since the aim of this paper is to reveal the proliferation of GIT practice across industries by examining the corporate sustainability reports, the dictionary-based text mining method is appropriate. In next section, we present our research in two phases: 1) building a GIT dictionary, and 2) examining GIT practices proliferation in non-IT industries.

**Phase 1: Building a Green IT Dictionary**

Dictionary building has been adopted by many research, such as Bengston & Xu (1995), Guo et al. (2016), Laver & Garry (2000), Loughran & McDonald (2011), Pennebaker et al. (2015), and Young & Soroka (2012). However, there is not a commonly-adopted dictionary building process in these research. In this paper, we follow the semi-automatic dictionary process developed by Deng et al. (2017) to build the GIT dictionary. According to Deng et al. (2017), the dictionary building process consists of five steps (and many iterations), namely, 1) corpus creation, 2) pre-processing, 3) entry identification and categorization, 4) extension and simplification, and 5) validation. We present our dictionary building process step-by-step as follows.

**Step 1. Corpus creation.** The corpus is the source from which a dictionary is developed. According to Deng et al. (2017), a good corpus should be relevant, appropriate, and complete. To develop a corpus for GIT dictionary building, we collected sustainability reports of big IT companies, technical reports issued by Global e-Sustainability Initiative (GeSI), and relevant newspaper and magazine articles (see Table 2). Specifically, we collected: 1) the most recent corporate sustainability reports of IT companies in the 2015
Fortune 500 when available; 2) technical reports or studies on GIT issued by GeSI which cover a period from 2008 to 2015; 3) newspaper articles and magazine articles identified in ProQuest by searching “Green Information Technology”, “Green ICT”, “Green information and communication technology”, “Green IT”, “sustainable IT”, “Green Computing”, “sustainable ICT” in ‘anywhere except full text’ without limitations on publication date. The aim of including different sources is to ensure the triangulation of data. In total, we collected 172 documents that contain 655,053 words (18,075 unique words). We imported these documents into WordStat, a text mining software, to assist the following dictionary building.

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of Documents</th>
<th>Unique / Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate sustainability reports</td>
<td>29</td>
<td>9,496 / 232601</td>
</tr>
<tr>
<td>Technical reports</td>
<td>14</td>
<td>12,259 / 331,172</td>
</tr>
<tr>
<td>Newspaper article</td>
<td>56</td>
<td>3,422 / 26,054</td>
</tr>
<tr>
<td>Magazine article</td>
<td>73</td>
<td>6,447 / 65,226</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>172</strong></td>
<td><strong>18,075 / 655,053</strong></td>
</tr>
</tbody>
</table>

Table 2. The Corpus for GIT dictionary building

**Step 2. Pre-processing.** In this step, we conducted spelling check and stop words removal with the help of built-in functions of WordStat. Although all of the documents we collected are formal publications, it is still necessary to check the spellings after importing the documents into the text mining software because of the possible importing mistakes (Deng et al., 2017). As to stop-word removal, we conduct this based on the built-in stop-word dictionary in WordStat. The aim of stop-word removal is to remove irrelevant words, such as, “a”, “the”, and “or”.

**Step 3. Entry identification and categorization.** A frequency report of words was generated automatically by WordStat and used to identify the entries (i.e., words or phrases). We went over the words occurring more than 3 times and added the GIT-related words into the dictionary with the assist of the key-word-in-context function of WordStat. From the review of academic papers on GIT practice and the corpus documents collected, we notice that many GIT practices are named using phrases (e.g., data center, energy star, electronic waste, and environmental management system), instead of single words. Therefore, we examined thephrased in the corpus. To do so, we first used the phrase extraction function of WordStat to generate the phrases of length between 2 and 5 words and occurring more than 5 times. This results in 4,966 phrases. Then we went over the phrase list and added the GIT-related phrases into the dictionary with the assist of the key-word-in-context. To develop the categorization structure of the dictionary, we used both theory-driven and data-driven approaches. At the first level, we categorized GIT into two general categories based on previous GIT research, namely, Green IT and IT for Green (reference). Then, at the second level, we categorized Green IT into four categories (i.e., design, manufacturing, use, and disposal) by adopting a life cycle perspective. We only keep two categories (i.e., use and disposal) in this paper because our main focus is non-IT industries’ GIT practices. We categorized IT for green into four categories (i.e., teleworking, dematerialization, green management information system, and smart for green) based on our review of previous academic papers on GIT. Since our aim is to build a GIT dictionary which can be used to identify different GIT practices, we adopt an inductive analysis to develop the third level of the categorization structure. We went over the entries identified and categorized them into different second-level categories. Then with the assist of the co-occurrence analysis functions (e.g., dendrogram and link analysis), we developed the third-level categories and further categorized the entries into them. After the first round of entry identification and categorization, we checked the leftover words and phrases for several rounds to identify relevant entries overlooked in previous rounds. In total, 18 third-level categories and 194 entries (26 words and 168 phrases) were identified.

**Step 4. Extension and simplification.** To extend and simplify the initial dictionary, we conducted the synonym examination and stemming (when appropriate). First, we checked the synonyms of the 26 words in our entries and identified another 3 words. During this step, we noticed that our dictionary include both British and American spellings. To further extend the dictionary, we complemented two types of spelling when appropriate, and this identified another 11 entries. To simplify the dictionary, we adopted stemming whenever appropriate (e.g., replacing “systems” and “system” with “system”, replacing “telework”, “teleworking”, “teleworker”, and “teleworks” with “telework”, and replacing “videoconference”, “videoconferences” and “videoconferencing” with “videoconference”). This step reduced the dictionary from 208 entries to 151 entries.
**Step 5. Validation.** To validate the dictionary built above, we compared the dictionary with the GIT practices identified in academic papers (i.e., Butler, 2011b; Corbett, 2010; Lee, Park, & Trimi, 2013; Lunardi, Alves, & Salles, 2013; Trimi & Park, 2013). In this step, we excluded Loeser (2013) and Sayeed & Gill (2008) because the GIT practices listed in their study are highly technical and, thus, inconsistent with our purpose of examining non-IT companies' GIT practices. Furthermore, of the GIT practices identified in previous research, some are more appropriate for IT companies than non-IT companies (e.g., IT product packaging and removal of toxins from IT products), and some are not at the organizational level (e.g., smart city planning and smart industry). These practices are also excluded from the comparison. Table 3 shows the result of the comparison.

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of GIT practices covered</th>
<th>Number of appropriate GIT practices for non-IT companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butler (2011b)</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Corbett (2010)</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Lee, Park, &amp; Trimi (2013)</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Lunardi, Alves, &amp; Salles (2013)</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Trimi &amp; Park (2013)</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71</strong></td>
<td><strong>82</strong></td>
</tr>
</tbody>
</table>

**Table 3. Results of comparison between the initial GIT dictionary and academic papers**

As Table 3 shows, our initial dictionary covered 86.6% (i.e., 70 out of 82) of the GIT practices identified by previous academic research. We then revisited the corpus with the aim of addressing the formerly overlooked GIT practices. We notice that IT sourcing, which was overlooked by us, is an important part of non-IT companies’ GIT practice. Therefore, we added this category into green IT and identified several entries. In addition, inspired by the practices identified by academic papers, we added many entries for other categories. In total, 17 new entries were added. After stemming, the final GIT dictionary included 20 categories and 158 entries. For example, *E-Waste* includes entries such as *WEEE*, *electronic waste*, and *electronic recycle*. Figure 1 shows the category structure and the entry distribution of the GIT dictionary.

![Figure 1. The Category Structure and Entry Distribution of the GIT Dictionary](image-url)
Phase 2: Examining Green IT Practices in non-IT Industries

In this section, we examined the GIT practices across industries by analyzing the corporate sustainability reports. Corporate sustainability reports have been used in previous sustainability research as a valid data source (see Bonilla-Priego et al., 2014; Fuisz-Kehrbach, 2014; Hahn and Lilfors, 2014). Examining corporate sustainability reports allows researchers to get a broad view of a corporation’s sustainability practice (Sharma & Henriques, 2005). The sustainability reports were collected through the Global Reporting Initiative (GRI) Sustainability Disclosure Dataset, which includes more than 38,000 corporate sustainability reports. In this paper, due to the limitation of time and scope, we collected the American companies’ 2014 sustainability reports that adopted the GRI G4 reporting guideline (i.e., the most recent reporting guideline) for the following analysis. Only the industries of which more than 3 companies issued the sustainability reports in 2014 were included in our sample. We used this thumb-up rule to avoid one industry being represented by too few of companies. In total, our sample included 129 reports that across 20 industries. Although our focus here is on non-IT industries, we retained the two IT industries (i.e., Computer and Technology Hardware) as benchmarking. The 129 reports were imported into WordStat and cleaned before analysis. To facilitate the discussion, we define a concept, Adoption Rate (AR), as follows:

\[ AR = \frac{\text{Number of companies adopting the GIT practice in one industry}}{\text{Number of companies in the industry}} \]

For example, of the 10 companies in the Energy industry, 5 adopted the Building Management System; therefore, the AR of Building Management System in the Energy industry is 50%. Based on the calculation of AR, a general comparison between proliferations of Green IT and IT for Green across industries is shown in Figure 2. From Figure 2 we can see that all the industries examined in this paper have adopted GIT practices to this or that extent, and with the focus on whether Green IT, IT for Green, or both. The wide adoption of GIT practices reflects a high awareness of the important role of IT in sustainability management. Interestingly, the ARs of IT for Green in all industries are higher than 60%, while the ARs of Green IT show a broad range from 0% to 100%. This is unsurprisingly given the different focuses and features of Green IT and IT for Green and the distribution of our sample across industries. Indeed, in most of the non-IT industries, IT for Green is more adopted than Green IT practices, while, in the IT industries, the situation is reversed. One interesting phenomenon is that all Mining companies examined in this paper adopted the IT for Green while none of them adopted Green IT. Considering the role of IT for Green in helping companies ensure their compliances to environmental laws and regulations, such contrast seems not to be so surprising.

![Figure 2. GIT Practices across Industries: A general Trend](image-url)
To reveal the GIT practices proliferation across industries in more details, we developed a heatmap based on the calculation of the ARs of each GIT practice across industries (see Figure 3). A heatmap is a visualization tool that reveals the relationships between a large number of words and categories of words against a large number of classes of categorical variables (Péladéau & Stovall, 2005). In a heatmap, the relative frequencies are represented using color brightness rather than numerical values, facilitating the identification of high- or low-frequency cells. In our case, the brightness of one cell represents the AR of the corresponding GIT practice in the corresponding industry.

Figure 3 shows two general patterns on the proliferation of GIT practices across industries. First, from the perspective of industry, two IT industries (i.e., Computers and Technology Hardware) do perform as benchmarks regarding GIT practice. Of the non-IT industries, Automotive, Financial Services, Real Estate, and Energy Utilities widely adopted GIT practices, while Chemical, Metals Products, Public Agency, and Mining adopted GIT practices to a much lesser extent. Second, from the perspective of GIT practice, Energy Star, Online Service, Building Management System, Environmental Management System, and Energy Management System are most widely adopted GIT practices, while Engine Management System, Traffic Management System are only adopted by a few of industries. In addition, as shown, Environmental Management System, Data Center, and Smart Logistics are adopted by all companies in Automotive, Computers, and Railroad industries, respectively. Specifically, in terms of the second level GIT practice categories, Figure 3 also shows some patterns. In IT sourcing, Energy Star is the most widely recognized certificate of IT product. Among the four perspectives of IT use, Virtualization received the most attention across industries. E-Waste also has been addressed by most of the industries except for Healthcare Products, Metals Products, Public Agency, and Mining. Of the IT for Green practices, both the most and the least widely adopted ones are in the sub-category, Green MIS. It is clearly shown that the Green MIS addressing general sustainability issues (i.e., Building Management System, Environmental Management
System, and Energy Management System) are more popular than the Green MIS addressing specific sustainability issues (i.e., Engine Management System and Traffic Management System). As to Smart for Green, the Smart Logistics is the most widely adopted GIT practices, while the Smart Metering and Smart Grid are only adopted by specific industries, such as Energy Utilities. The analysis reveals that the proliferation of GIT practices into different industries is dependent on the specific features and the requirements of the industries.

Discussion and Conclusion

In this paper, we examined the GIT practices across industries using a dictionary-based text-mining method. This paper has many implications. Theoretically, the dictionary itself reveals the current popular GIT practices recognized by corporations, media, and researchers, which presents a broad view of GIT practice. Second, we developed a dictionary that can be used to identify and analyze GIT practices in textual data. Used properly, the dictionary can be used in future research to analyze many GIT-related issues, such as GIT adoption, monitoring, and evaluation. To the best of our knowledge, this is the first paper that uses a text-mining method to study GIT practice issues. Third, although this paper embraces a practice-based perspective, the findings do provide some insights for future GIT research. As mentioned at the beginning of this paper, the fact that GIT is an umbrella concept that consists of many practices has been, to some extent, overlooked by many GIT researchers. Such overlook has limited the rigor and the relevance of GIT research. For example, taking a look at the GIT adoption research, one can easily find that most of the research models proposed are examining the adoption of GIT, rather than the specific GIT practices (Cai, Chen & Bose, 2013; Chen et al., 2009; Gholami et al., 2013; Molla, 2009). While previous research tends to treat GIT as one ‘general’ practice and identify many ‘general’ antecedents (e.g., institutional factors, organizational factors, and technological factors) for its adoption, our analysis shows that, even in one industry (e.g., with similar antecedents), the adoption rate of different GIT practices is different. This suggests that, in case of GIT adoption, technology matters. Similarly, our analysis also shows that the context of GIT adoption (i.e., industry) matters. Therefore, we propose that future GIT adoption research should shift from focusing on a general concept (i.e., Green IT) to examining the ‘specific’ practices in ‘specific’ context. Another implication suggests the use of resource-based view (RBV) for GIT research. Based on the RBV, previous research proposed that implementing GIT initiatives could help companies develop and sustain their competitive advantages (Vyokoukal, Wolf, & Beck, 2009). However, as shown by our data, while some GIT practices have been widely adopted by most industries, whether adopting these GIT practices can sustain the competitive advantages is remained to be seen and further examined. This paper also has some practical implications. For non-IT industries, IT industry seems to set a benchmark and provide best practices for GIT. For IT vendors, it is necessary for them to understand the actual use of GIT across different industries and provide the GIT technologies according to the features and requirements of one specific industry. This paper is not without limitations. First, the design of this research is based on the assumption of what being reported actually reflects what being practiced. We are mindful about the shortcoming of this practice and view it as an inevitable methodological trade-off for a systematic comparative analysis. Future research could use other methods (i.e., survey and field study) jointly as triangulated validations of the results. Second, due to the limitation of the scope, we only analyze a cross-sectional data that consists of 129 corporate sustainability reports of one particular year. Future research could expand the sample to improve the generalizability of the results, as well as examine a longitudinal data to reveal the GIT practice evolution over time.

Reference


