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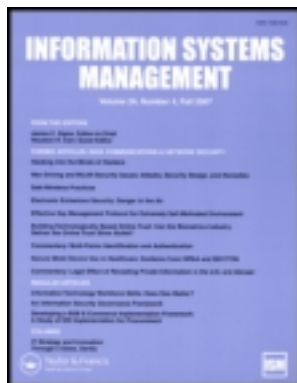
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# Open Source CRM Software Selection using the Analytic Hierarchy Process

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**Open source Customer Relationship Management (CRM) software is frequently used to support a firm's front-end activities such as sales, marketing, and customer service. This article presents an efficient decision making framework to select the best open source CRM software using Analytic Hierarchy Process (AHP) from not only the functionality aspect, but also from the organizational perspective. This framework would be useful for managers who intend to adopt open source CRM software for their organization.**

**Keywords** open source software; customer relationship management (CRM); open source CRM; analytic hierarchy process (AHP); sensitivity analysis

## 1. INTRODUCTION

Today, IT and its application has become an integral part of business organizations. It plays a critical role in improving the effectiveness and productivity of all the processes in the company. There are many different kinds of software for enterprises such as accounting software, human resource management (HRM) software, supply chain management (SCM) software, enterprise resource planning (ERP) software, customer relationship management (CRM) software, and so on. Firms use these software to operate and manage not only their internal activities but also their external activities easier and more productively. Among the aforementioned software, CRM is one of the emerging software which is becoming an essential tool for supporting external operations, particularly in sales, marketing, and customer services. Companies make large investments on CRM software in order to achieve the maximum return from their customers through sales, marketing, and

other related activities. Comparing to the other enterprise software like ERP or SCM, CRM software is more popular and has been adopted and utilized widely. The market for CRM software therefore is becoming stable and clearly segmented. For large companies with strong financial capability, the CRM software belongs to the first category, for example Microsoft Dynamics CRM, Oracle CRM, SAP CRM, Salesforce.com, NetSuite (CRMsoftware360, 2012a), which are large scale and proprietary software. These software don't match well with the requirements and the economic conditions of small and medium enterprises (SMEs). Hence, a second category in the CRM market, which is specifically for these types of companies, has appeared. The main product in this second segment is the open source CRM software.

With the open source software trend, open source CRM software is a very attractive alternative for enterprises, especially for small and medium-sized companies. However, a key issue is how enterprises can choose the best open source CRM software that would suit their needs. Because open source CRM software differ from commercial CRM software, the criteria for selection also differ. The purpose of this research is to suggest an efficient decision making framework to select the best open source CRM software from a firm's perspective. To address this issue, this study uses the Analytic Hierarchy Process to select the best open source CRM software not only from the functionality aspect, but also from the organizational aspect. We expect that the results of this study will be useful for the managers who have intention to adopt open source CRM software in the future.

## 2. LITERATURE REVIEW

### 2.1. The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), is designed to solve complex multi-criteria decision problems. It is a flexible and powerful tool for handling both qualitative and quantitative multi-criteria problems. AHP is aimed at integrating different measures into a single overall

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score for ranking decision alternatives. Its main characteristic is that it is based on pairwise comparison judgments (Ngai & Chan, 2005). Besides, the AHP steps are not too complicated, and several software tools can be used to perform the calculations to save time and effort instead of doing them manually.

AHP is the most popular method among various multiple criteria decision-making (MCDM) methods such as ANP (analytic network process), Fuzzy ANP, Fuzzy AHP, and so on, because of its intuitive approach and ease of use. Sipahi and Timor (2010) show that, of the 232 MCDM articles published in reputed international academic journals during 2005–2009, AHP was used in 169 articles and the rest used other techniques. AHP is used by both individuals and groups to deal with not only personal issues but also general problems. AHP has also been utilized in corporate planning, portfolio selection, cost/benefit analysis, resource allocation, conflict resolution, estimation and prediction, and so forth (Saaty, 2001). Besides its main functions, “AHP also enables people to test the sensitivity of the solution, or outcome, to changes in information” (Saaty, 2001). Moreover, the decision makers can revise the AHP model by expanding the elements of the designed hierarchy and modify their judgments by solving the up-to-date problem and develop sound solutions over time. AHP is not a static framework, but dynamic in its features and functions.

AHP has been applied in numerous fields, for instance, manufacturing, education, logistics, e-business, IT, R&D, telecommunication, finance and banking, defense and military, government, tourism and leisure, archaeology, auditing, mining industry, sports, and politics (Sipahi & Timor, 2010). Common examples of using AHP for decision-making are car purchasing (Byun, 2001), vendor selection (Tam & Tummala, 2001), IS project selection (Muralidar & Santhanam, 1990; Schniedejans & Wilson, 1991), and software selection (Kim & Yoon, 1992; Mamaghani, 2002). In the software selection problem, there are several recent studies reported on the use of AHP for different kinds of programs such as antivirus and content filtering software, executive information system, simulation software, and so forth. For example, enterprise solutions like knowledge management system (Ngai & Chan, 2005) or ERP system (Cebeci, 2009; Teltumbde, 2000; Wei, Chien, & Wang, 2005) have been selected by applying the AHP technique. Thus, because of its suitability and effectiveness, we have adopted AHP in our approach for CRM software selection.

## 2.2. Customer Relationship Management (CRM)

In recent years, CRM has been one of the prevalent topics in academia and practice for both scholars and managers (Becker, Greve, & Albers, 2009; Boulding, Staelin, Ehret, & Johnston, 2005; Kumar, Lemon, & Parasuraman, 2006). The management of customer relationship has become a top priority for many enterprises. In many competitive markets, businesses invest substantially in CRM implementation (Bohling et al., 2006). There have been many definitions provided for CRM; however, no single definition has emerged as the complete and

accurate CRM definition so far because the CRM theory and practice is still evolving and developing. CRM is not just a software application, but it is a strategy for doing business. CRM focuses on building individual customer relationships for the purpose of creating and maintaining a loyal customer base, and it is used to learn more about customers' needs and behaviors in order to build a long-term relationship with the customers to fulfill both short and long-term business goals of the organization (Kaderják & Simon, 2009). In essence, CRM is a cross-functional process that focuses on initiating, maintaining, and retaining long-term customer relationships (Reinartz, Krafft, & Hoyer, 2004).

CRM software helps organizations implement effective CRM. Nowadays, CRM software is not an option, but a necessary and integral part of any modern business that seeks to maximize revenue and continue growing as a business. By integrating all the data about sales, current customers, associated companies, and employees throughout the various departments, CRM software enables enterprises to seamlessly handle marketing, sales, and customer service as a single package. It supports different business processes and maintains the right information about its customers and organizes that information for proper analysis. This is useful for making strategic decisions on future sales and marketing campaigns.

## 2.3. Open Source CRM Software

Open source CRM software is any type of software program that deals with CRM and is able to be modified by any user or software developer because the source code is made public. A few years ago, open source CRM was not even thought about. Open source was used only in specific domains such as utility software and applications, operating system, database, and web server. However, recently, the perception has changed, and now open source CRM is highly respected and becoming quite popular.

Because of the intensity of technological developments, the widening of the set of solution methods and the strengthening of the CRM market, CRM products today have reached the technological complexity level that makes them available for small and medium business as well (Kaderják & Simon, 2009, pp. 916–917).

Open source CRM software packages are highly rated by their users and compete quite well with the commercial products. Especially, open source CRM solutions are pretty attractive to SMEs, thanks to several distinct advantages. The most crucial factor is cost. Open source CRM software is almost free or free for a basic-function edition. In addition, the features offered are appropriate and able to meet the enterprise requirements. Thus, SMEs can save a significant reduction in expense for implementing a CRM solution while still having a fully functional CRM system. Even though enterprises may employ a consulting agency for purchasing and implementing an advanced edition, the savings are still much more compared to the cost of buying proprietary software. The SMEs in developing countries

are the prospective clients for open source CRM software. In the United States, the utilization and consideration of open source CRM software is also on the rise. Some of the most popular open source CRM software available today include: SugarCRM, vTiger, Daffodil CRM, Centric CRM, Anteil CRM, and SellWinCRM.

## 2.4. Open Source CRM Software Selection Using AHP

There are many studies on CRM reported in the literature; however, most of them have focused on CRM theory, empirical practices, case study in CRM software adoption, and measuring CRM performance. There are a few studies related to applying the MCDM approach. For example, Oztaysi, Kaya, and Kahraman (2011) used the ANP for a comparative study about CRM performance of e-commerce firms. Keramati and Sangari (2011) have suggested a framework to investigate the critical factors associated with implementation of CRM through Fuzzy ANP approach. Colombo and Francalanci (2004) have introduced a hierarchical ranking model for the selection of CRM packages based on architectural and functional aspect. However, there are no prior studies or in-depth research in applying AHP for selecting open source CRM software. The purpose of this article is to suggest a comprehensive framework for open source CRM software selection from a firm's perspective. Among the MCDM techniques such as AHP, ANP, Fuzzy AHP, Fuzzy ANP, and so on, AHP is simple, intuitive, and easy to apply. Because of these characteristics, AHP is a suitable methodology to meet our research goal.

In addition, a similar software—ERP software—has been examined to create a framework for ERP software selection using the AHP method (Wei et al., 2005), Fuzzy AHP (Cebeci, 2009), and so on. This work is related to our research because ERP and CRM systems are enterprise solutions and have some common features in the selection process.

## 3. THE AHP MODEL

This article suggests a MCDM model using AHP for open source CRM software selection. Based on the developed model, an enterprise can examine and evaluate the various aspects of an open source CRM software, or use it as the standard for comparing and opting for a particular open source CRM software. By considering various sides of the selection issue from an enterprise standpoint, the developed model helps the firm select an open source CRM software that is not only appropriate to the firm's capabilities but also meets its requirements. In this research, an AHP-based approach is used to design and develop the MCDM model for open source CRM software selection.

Because of the holistic viewpoint that we want to achieve, we have considered all the criteria in a consistent and logical way in the development of the MCDM model. It is a common problem that researchers are likely to face when employing a certain MCDM technique to any topic, not just the open source CRM software selection issue. Considerable care has been taken in the development of the operational definitions of all the criteria, which is time-consuming and requires much effort. First, we established the initial descriptions of all the criteria and refined these descriptions to improve their reliability with help from the related literature. We extracted the crucial information and integrated it with our descriptions to get the complete definitions of all the criteria.

The general goal is to select the appropriate open source CRM software for an organization. By decomposing this overall goal into lower-level fundamental objectives, the full hierarchy could be constructed with five levels. Figure 1 shows the structure of CRM selection hierarchy with the overall goal, different criteria, sub-criteria, concerns, and alternatives. The CRM selection hierarchy has been derived based on the existing literature, and each level of the hierarchy is briefly described below.

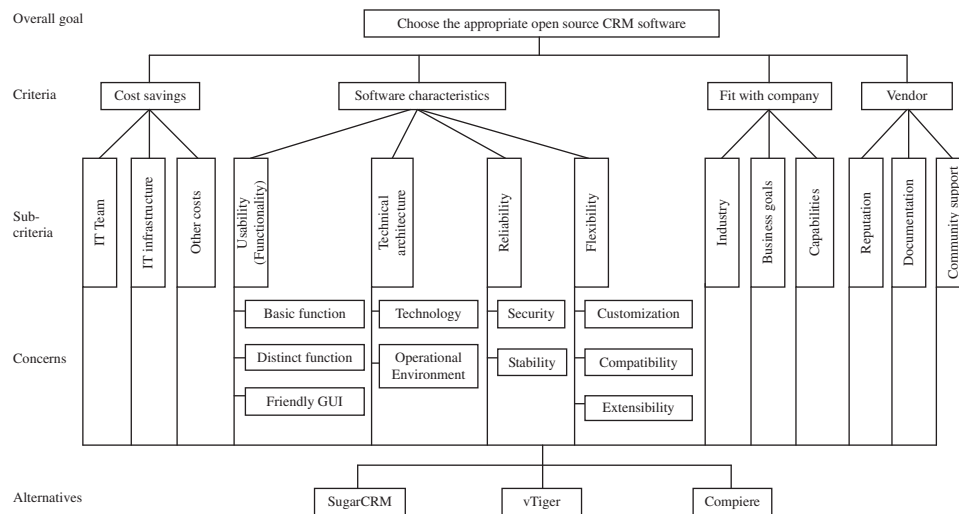


FIG. 1. The hierarchical structure for open source CRM software selection.



### 3.1. Operational Definition

The root node of the CRM software selection hierarchy is the overall goal, namely, “choosing the appropriate open source CRM software.” This overall goal is accomplished through four criteria that satisfy it. They are “cost,” “characteristic,” “fit with company,” and “vendor.” Each criterion is further expanded into sub-criteria with specific objectives and concerns. Finally, the alternatives are included at the bottom level of the CRM selection hierarchy. A brief explanation of each component or factor in the AHP hierarchy (Figure 1) is given below.

#### 3.1.1. Cost

Cost refers to the total cost that firms have to spend to implement a specific open source CRM software (Lien & Liang, 2005; Lien & Liang, 2007; Ngai & Chan, 2005). Cost is a common factor influencing the purchaser to choose the software (Davis & Williams, 1994). Open source CRM software is free with respect to license fee, but it doesn't mean that the organizations don't incur any cost in implementing the software. From the open source software perspective, it reduces the total cost for the CRM software adopter; however, there are still other costs which firms have to bear. These costs are described later.

- *IT team:* To implement open source CRM software by themselves, organizations should have a good IT Team that can take on the responsibility for that mission. They can utilize the professional IT personnel from their IT department, or if they don't have such talent, they must hire outside resources or invest in their existing IT staff to be able to accomplish this goal.
- *IT infrastructure:* “IT infrastructure consists of sharable and reusable IT resources that provide a foundation to enable present and future business applications” (Shang & Seddon, 2000, p. 1006; see also Earl, 1989; Keen, 1991; McKay & Brockway, 1989; Niedman, Brancheau, & Wetherbe, 1991). According to Weill and Broadbent (1998, p. 26), “infrastructure building is one of the fundamental management objectives in IT investment.” Adopting new software system may require a company to improve or expand its current IT infrastructure to be able to install new CRM software. Besides, it is maybe essential to meet development needs of the company in the future, although the company's abilities are enough now. Making this decision depends on the vision and aim of each company.
- *Other costs:* This relates to all other expenses incurred compared to the aforementioned two costs during the adoption process of an open source CRM software. It can be consulting cost during the implementation period in case the organizations need it, or the cost of end-user training, and so on.

#### 3.1.2. Characteristic

Characteristic pertains to the features of an open source CRM software, including the functionality aspect as well as the technology aspect. Functionality is usually considered as the basic factor when selecting a software solution. Moreover, it is one of the six key quality attributes for the software quality model according to the ISO 9126 standard (Bache & Bazzana, 1994). It has been used in previous software selection scenarios, such as the multimedia authoring system selection process (Lai, Trueblood, & Wong, 1999), AHP software evaluation (Ossadnik & Lange, 1999), and so on. The sub-criteria under the “characteristic” criterion are briefly discussed later.

- *Usability:* It refers to the ability of an open source CRM software to meet the company's requirements through its functionality (Karlsson, Wohlin, & Regnell, 1998; Lien & Liang, 2005; Lien & Liang, 2007; Tsai, Lee, Shen, & Yang, 2009). In other words, how well does the software meet the user's needs and requirements (Ngai & Chan, 2005). It is evaluated as one of the software quality factors in the McCall software quality model (McCall, Richards, & Walters, 1977) and it also one of six main characteristics of the ISO 9126 standard (Bache & Bazzana, 1994). Usability is measured in terms of the following attributes:
  - i. *Basic functions:* These are must-have functions of any CRM software to develop CRM strategy within a company. Typically, they are sales force automation (SFA), marketing automation, call center/help desk for customer service and support, field service, calendaring, collaborative selling and planning, and so on. (Adebanjo, 2003; Ang & Buttle, 2006; Colombo & Francalanci, 2004; Xu, Yen, Lin, & Chou, 2002).
  - ii. *Distinct functions:* In addition to basic functions and modules, each open source CRM software also provides special and extended functions to make it more attractive and gain an edge over the competition. These distinct functions provide more benefits for its users.
  - iii. *Friendly GUI (Graphic User Interface):* The well-organized information and good structured design in user interface can help the users easily to get acquainted with the software and master it more quickly. In addition, it will help the software increase the level of “user friendliness” (Herzog, 2006; Karlsson et al., 1998; Wei et al, 2005).
- *Technical architecture:* This criterion considers open source CRM software from the technology aspect and the architectural components of the software. These elements decide the platform independence capability of the solution. It has two main aspects:
  - i. *Technology:* This is concerned with what technologies have been used to build and operate the open source

CRM software. For example, what programming language has been used to write the source code, what is the type of application that the open source CRM software belongs to (e.g., whether it is desktop application or web-based application, is it operated using cloud-computing technology or software as a service [SAAS], etc.).

- ii. *Operational environment*: This relates to all the factors and accompanying components that play a supportive role such as the environment so that the software can run and work normally. These are operating system, web-server, database, and so on. Not just open source CRM software, but most of the open source software usually apply emerging and open source technology such as Linux, Apache Tomcat, MySQL, Postgres, (etc.) to decrease costs and increase flexibility for both customers and vendors.
- *Reliability*: It refers to the ability of the software to be reliable for the customer, and the degree of reliability (Cebeci, 2009; Hatzithomas, Stamelos, Fotiadis, & Mylonakis, 2007; Karlsson et al., 1998; Lien & Liang, 2007; Tsai et al., 2009; Wei et al., 2005). According to McCall et al. (1977, section 3, p. 5), it is defined as “the extent to which a program can be expected to perform its intended function with required precision.” From Bache & Bazzana’s (1994) point of view, reliability is characterized as the capability of software that could maintain its level of performance under stated conditions for a stated period of time. Typically, reliability includes the following two aspects:
    - i. *Security*: This refers to the ability of the open source CRM software to ensure the privacy of customer information and sensitive business data of the company (Lien & Liang, 2007; Ngai & Chan, 2005; Wei et al., 2005). It involves authentication, permission for each user in the CRM system, different levels of access rights, database protection, and so on. In addition, the recovery ability of the software is also equally important. It should have the automatic data recovery and data backup function.
    - ii. *Stability*: It refers to the ability that the open source CRM software can work normally at all times without interruption and serious errors (Lien & Liang, 2007; Wei et al., 2005).
  - *Flexibility*: This is concerned about whether the open source CRM software is a flexible system or not (Cebeci, 2009; Karlsson et al., 1998; Lien & Liang, 2005; McCall et al., 1977; Ngai & Chan, 2005; Wei et al., 2005). Can the CRM software be adapted to satisfy with various changes in functionality and needs of the company (e.g., increasing in the number of users in the CRM system)? “Flexibility allows us to bridge the functionality gap between out-of-the-box functionality and the close functional fit provided by a customized

system” (Herzog, 2006). It has the following three specific dimensions:

- i. *Customization*: Refers to the ability and different levels that customers can customize the open source CRM software. The customization effort can be distributed among a larger number of participants. The customization steps may be easy or complicated to accomplish, depending upon what parts of the software are being customized. The administration role for the software should provide mechanisms to be able to configure or set up not only different user interfaces but also suitable functions for various users depending on their role and permission. The open source CRM software should support the developer to modify the data structure and data fields through the GUI rather than changing the source code of the software. The more customizable the open source CRM software is, the less the developer has to rewrite the source code.
- ii. *Compatibility*: Is the new CRM software compatible with existing systems of the company or not (Cebeci, 2009)? Can the software be integrated with other information systems, new platforms, or devices such as smart phones, tablets, phablets, etc., to support future business operations or to perform additional functions such as collecting customers’ opinions in real time?
- iii. *Extensibility*: It refers to the scalability of the open source CRM software. Scalability refers to the ability to scale up without degradation in performance when the number of users or the tasks which need to be performed and the amount of data increases (Tiwana, 2002). “A system that does not scale to support all future users is a disaster waiting to happen” (Herzog, 2006, p. 23). Moreover, extensibility also relates to the following questions—Is that software easy to extend with new functions or add new utility plugins, etc., and is the degree to which it can be extended high or low? How about the ability to upgrade to higher versions?

### 3.1.3. Fit With Company

Although a specific open source CRM may be powerful and robust, is that solution suitable for the business strategy and the current management of the firm? “To satisfy business strategy, the software should satisfy the industrial characteristics and the business goals and adapt to dynamic business environment” (Wei et al., 2005, p. 52). Hence, it requires the alignment of CRM software with the current business needs and IT capabilities of the firm (Oztaysi et al., 2011). This objective is divided into three smaller criteria.

- *Industry*: Is the software really suitable for the industry in which the company is operating in? Each sector has unique characteristics and “business rules differ dramatically from industry to industry” (Shahin, 2008,

p. 22), so that the strategies for customer also have different requirements. "The enterprises need a CRM software that is built from the ground up according to the way they do business" (Shahin, 2008, p. 22). Thus, whichever open source CRM software that is able to fulfill those differentiations will support CRM activities for the company in a more effective and efficient manner.

- *Business goals:* Each company has both its own development goals and specific CRM objectives. Based on prior studies, it is evident that organizational strategy is one of the characteristics of the firm that influences the CRM adoption (Damanpour, 1987; Ettlie, 1983; Ettlie, Bridges, & O'Keefe, 1984; Ko, Kim, Kim, & Woo, 2008; Ko, Kincade, & Brown, 2000). So, are the information processing methods supported by the CRM software appropriate for the current operating procedures and the goals of the company?
- *Capabilities:* This refers to the fit of the company's resources that are needed for implementing and maintaining the open source CRM software or the extent to which an open source CRM software is pertinent to the enterprise's capabilities, for instance, scale, finance, human resources (not only technical but also other department staff), technical skills, and so forth. Hence, open source CRM software which has a good fit with the resources of the firm can help to improve not only the interaction between the firm and its customers, but also the effectiveness of CRM project because of "the alignment of technological capabilities with CRM initiatives, which is referred to as the Technological Alignment" (Oztaysi et al., 2011, p. 9791).

#### 3.1.4. Vendor

In case of proprietary CRM software, the quality of vendor support and its characteristics are very important in the selection of CRM software (Byun & Suh, 1996; Lien & Liang, 2007; Min, 1992; Ngai & Chan, 2005; Wei et al., 2005). Although the supplier of an open source CRM software doesn't have the same level of importance compared to a commercial CRM software, vendor characteristics are still important in selecting an open source CRM software. It involves the following three criteria.

- *Reputation:* The fame and popularity of an open source CRM software partly reveals the ability of the vendor and the capability of the product. The reputation of the vendor could be evaluated by the popularity of the software in the user community, the number of downloads, the awards that the vendor has won, and so on. This factor is usually considered in various kinds of software selection processes, for instance, deciding on a knowledge management tool (Ngai & Chan, 2005), ERP system selection (Cebeci, 2009; Wei et al., 2005), and so on.

- *Documentation:* It refers to the quality of documents or reference materials related to the open source CRM software that the vendor provides to guide the users as to how to set up, operate, and customize the software. "The availability of documentation is important, including technical documentation" (Bruce, Robson & Spaven, 2006, p. 128). In general, documentation plays a major role in helping the firm learn how to use and master the open source software.
- *Community support:* The bigger the community that an open source CRM software has, the more support the firms can have. Community is a crucial part in the growth of an open source software. They can contribute to the development of the open source software and make it larger and more powerful. Support from the community is often in the form of documentation, plugins or add-on packages, bug detection, module development, and so on. "The amount of activity within the community is important to an open source project, as a thriving community will drive updates for the software, and increase the number of bugs reported and removed" (Bruce et al., 2006, p. 128).

### 3.2. Alternatives

There are many open source CRM projects listed on sourceforge.net with numerous open source CRM software available for download. Some of the well-known open source software specializing in CRM are: SugarCRM, vTiger, SplendidCRM, CentricCRM, Salesforce.com, Tine 2.0, phpBMS, OpenCRX, Hipergate, and CiviCRM. In addition, there is another type of open source CRM software that combines CRM and ERP to provide a unique solution. Examples of this type of software are Compiere, Opentaps, and OpenERP. Selecting a particular open source CRM software that best suits the needs of an organization might not be a trivial task. One has to take into account the factors that have been discussed earlier and balance them against the needs of the organization. The proposed AHP model would help an organization make that decision in a systematic way. In order to demonstrate the use of the proposed AHP model, we use a subset of the available open source CRM software, though the methodology can be used for any number of CRM software to select from. Specifically, we use SugarCRM, vTiger, and Compiere as the alternatives from which we want to select one CRM software.

Each alternative in the above subset has been chosen for its own reasons. SugarCRM and vTiger are the software that specialize in CRM function. However, in the market, there is another type of CRM software that combines CRM with other modules in an enterprise solution, usually ERP, for example Openbravo, Compiere, and so on. Hence, one alternative belonging to this kind of CRM software has been selected to diversify the recommended choices, as well as meet the various requirements of enterprises. After due consideration, Compiere



is chosen as the final candidate to consider compared to other open source ERP software, since the CRM module of Compiere is fully functional and more complete. SugarCRM and vTiger are also prominent open source CRM software and rated highly for SMEs by the CRM magazine (CRMsoftware360, 2012b) and CRM analyst (Lauren, 2011; Sudheer, 2011). Together with Compiere, these three dominate many lists of awards such as CRM magazine's (Myron et al., 2008, 2009, 2010, 2011) CRM Market Awards, CRM Buyer's Guide (2011) of TEC for SugarCRM, and Bossie Awards: The best open source applications (2008, 2009, 2010, 2011). Each of these three software is briefly described in the following subsections.

### 3.2.1. SugarCRM

SugarCRM offers open source CRM business software for both cloud-based and on premise (<http://www.sugarcrm.com/>). Its features include sales, marketing, customer support with e-mail, and mobile and social CRM integration. The basic functions supported by Sugarcrm are SFA, marketing automation, customer support, and reporting. The special features that SugarCRM provides are capabilities to manage e-mail from within it and integration with Microsoft Outlook. It also allows workers to access the system using mobile and offline settings. In addition, SugarCRM offers an easy and powerful feature to customize business process, user interface, and other features. For example, drag and drop user interface, creation of custom fields and modules, reveal and protect information based on user role and profile, and so on. SugarCRM is a web-based application. The technologies that SugarCRM mainly uses include LAMP (Linux, Apache, MySQL, PHP), JasperReports, however, it also runs on other platforms that support PHP such as Windows, Solaris, and Mac OS X. Microsoft IIS can be used as the web server while MS SQL and Oracle can be used as alternative databases.

### 3.2.2. vTiger

vTiger CRM is an enterprise-ready open source CRM software mainly for small and medium businesses (<http://www.vtiger.com>). Similar to SugarCRM, vTiger also offers its services on cloud-computing environment as well as on demand. Especially, it has versions for mobile and smart phones. At this time, vTiger can work on iPhone/iPod Touch/iPad, Android, and Blackberry. vTiger provides many usual CRM functions, such as SFA, customer support and service, marketing automation, inventory management, analysis and reporting, security management, and calendaring. Other distinct features are e-mail integration (plug-in for Microsoft Outlook, Mozilla Thunderbird extension), support for Asterish PBX phone system, RSS feed functionality, add-ons such as Office Plug-in for Microsoft Word, and Customer Portal. vTiger is a web-based application and built on LAMP/WAMP (Linux/Windows, Apache, MySQL, and PHP) technologies and other open source projects. vTiger is able to run in different Linux operating systems (e.g. RedHat, Debian, SuSe, Fedora, and Mandrake)

TABLE 1  
Top 3 Vertical Industries of Alternatives

| Alternatives | Top 3 Verticals   |
|--------------|---|
| SugarCRM     | Financial Services, Manufacturing, Technology                         |
| vTiger       | Financial Services, Manufacturing, Media                              |
| Compiere     | Discrete Manufacturing, Professional Services, Wholesale Distribution |

*Note:* Source: Myron et al. (2008).

because all the necessary software and executables are made available on these operating systems.

### 3.2.3. Compiere

Compiere is an integrated ERP and CRM software for SMEs. It also provides solutions on-premise and on the cloud (<http://www.compiere.com>). Besides the functions of ERP system, Compiere offers CRM functionality such as sales, web store (e-commerce) service, and customer history. Especially, Compiere has point of sale (POS) which fully integrates with other activities. Compiere Community Edition is a desktop application, while other editions are web-based applications. The programming language used to develop Compiere is Java. Compiere pursues innovative and robust architecture and technology such as model-driven architecture, MVC (model-view-control) model, ADD (Active Data Dictionary) concept, JavaEE, and cross-platform JavaClient. Hence, it is well-organized in terms of data structure and it can offer the ability for customers to change the information structure and adjust to new information needs. Database choices for Compiere are numerous, such as Oracle, PostgreSQL, and MySQL, Sybase, Firebird, Apache Derby, and EnterpriseDB, thanks to the Database Kit project for porting Compiere to multiple databases.

Table 1 shows the three major segments for each of the alternatives. As seen from the table, all three CRM software provide support for financial services, technology, manufacturing, and distribution. Picking a single product might require a more in-depth analysis of the product features and characteristics as well as the needs of the organization. The next section discusses application of our proposed AHP model for selecting a specific suitable product from the alternatives.

## 4. EMPIRICAL ANALYSIS

Based on the AHP model for open source CRM software selection discussed in the previous section, an empirical study has been conducted to demonstrate how to apply our model to determine which open source CRM software should be selected. The selection process is carried out based on the input provided by three domain experts in IT. One of the experts is the team master of bloter.net, known as a digital expert media site (<http://www.bloter.net>), where "bloter" is the combination of reporter and blogger. Another expert is an IT columnist who

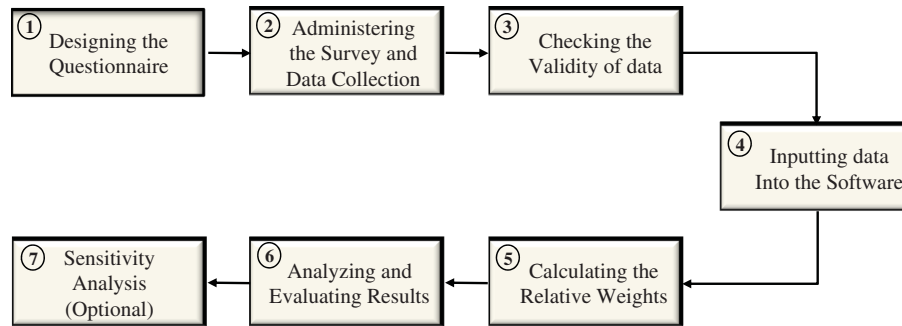


FIG. 2. The detailed steps in the empirical analysis process.

publishes his writings in many magazines and journals about new trends and different issues related to IT. The last is a professor of Management Information Systems. All of them have deep understanding and knowledge about open source software and have published articles on this topic.

The detailed steps of the empirical analysis conducted are shown in Figure 2 and briefly described below.

- *Designing the questionnaire*: The first step in the empirical analysis process is designing the questionnaire. The AHP questionnaire is structured in a specific format and is more prudish than a typical questionnaire used in an empirical study. Each question in the survey instrument is a comparison between two criteria/two alternatives based on a nine-point scale. The respondents are given sufficient directions and examples as to how to complete the survey. This ensures that the responses are reliable.
- *Administering the survey and collecting data*: After designing the questionnaire, it was sent to the respondents, particularly the three experts utilized in this research. The experts answered the questionnaire by expressing their judgment for the comparison items. Specifically, they performed the pairwise comparison between criteria, sub-criteria, concerns, and alternatives on the appropriately formatted questionnaire. Thus, the pairwise comparison data is gathered.
- *Checking the validity of data*: When the responses from the three experts were received, they were checked for validity before using them in the next step. The whole comparison data of each expert was entered into the AHP-specialized software, and the validity of the data was checked based on the inconsistency ratio. The data is deemed valid if this ratio is not larger than 0.1. Thus, the acceptable threshold value for the inconsistency ratio is less than or equal to 0.1, and this ratio is calculated automatically by the software. In our sample, the individual consistency ratio of each expert satisfied this requirement. In order to use the data from the experts, the intermediate step is to unify them. Each comparison question has three responses,

and the geometric mean of these three responses is calculated to generate a single response which represents for the opinion of the three experts. Thus, there is finally one comparison data (geometric mean) from the original three comparison data. This computation has been done by the researchers.

- *Inputting data into the software*: The hierarchy is built, and the geometric mean form of the comparison data is inputted into the AHP-specialized software.
- *Calculating the relative weights*: After all the necessary information is provided to the software, the final relative weights are calculated automatically by the AHP software. First, based on the priority matrices, the local priorities for the criteria, sub-criteria, and concerns are computed using the eigenvalue method. Then, the local priorities are synthesized across all criteria to determine the global weights. They are computed using additive aggregation with normalization of the sum of local priorities to unity, as given in the equation below (Ishizaka & Labib, 2009):

$$P_i = \sum_j w_j \times l_{ij} \quad (1)$$

where  $p_i$  is the global weight of the alternative  $i$ ,  $l_{ij}$  is the local priority, and  $w_j$  is the weight of the criterion  $j$ .

- *Analyzing and evaluating results*: Based on the priorities of the criteria and the relative weights of the alternatives computed by the software, the researcher or the user can analyze and interpret the results. Based on the final results and the specific issues that are being evaluated, an appropriate final decision could be made.
- *Sensitivity analysis*: This analysis is extended and optional. It is performed to investigate how sensitive the rankings of the alternatives are to changes in the importance of the criteria. It helps dive deeper into the results and enables the user to develop a better understanding of the impact of each alternative with respect to each criteria. With this additional knowledge based on different what-if scenarios, the user can come up with the most appropriate decision.

#### 4.1. Establishing Priorities

In this research, we have used the *Expert Choice 2000* software (Expert Choice, Inc., Arlington, VA, USA) for calculating and synthesizing the relative weights within the AHP process (step 4 and step 5). Based on the input related to experts' judgments, Table 2 shows the weights computed by Expert Choice software for all the criteria, sub-criteria, and concerns that are part of the CRM hierarchy developed in this research.

Table 3 shows the last step of computing the overall priorities for each of the alternatives by weighting according to their global priorities. Figure 3 displays the final weights (overall priorities) of each alternative, and, as indicated in Figure 3, SugarCRM is determined to be the best open source CRM software, since it has received the highest priority. In addition, the overall inconsistency ratio of this evaluation is 0.01, which is well within the acceptable inconsistency value of 0.1 for judgment.

#### 4.2. Analyzing and Evaluating the Result

According to the weights shown in Table 2 for the four main criteria under the overall goal in Figure 1, the criterion "Fit with company" is the most important criterion with the value of 0.335, and the next one is the "Characteristic" with the little lower weight of 0.323. The criterion "Vendor" seems to be not

considered highly important by the experts, since its priority is only 0.081, while "Cost" is the third important criterion with a relative weight of 0.261.

Among the sub-criteria of "Cost," "IT Team" and "IT Infrastructure" have the same priority (0.4), while the "Other costs" priority is just half of that (0.2). This means that the investments incurred for IT human resource and IT facilities are equally important and more crucial than the other costs.

For the "Characteristic" criterion, the sub-criterion "Reliability" has been evaluated as the highest with a value of 0.376 by the experts. Because CRM software works with all the customer data together with private business data of the company such as sales, expenses, revenues, and so on, the reliability of open source software must be very high. That is why the "Security" concern has a higher relative weight than "Stability." The second and the third important features are "Usability" with a priority of 0.322 and "Flexibility," which has the value 0.248. For the sub-criteria "Usability," two concerns, namely, "Basic function" and "Friendly GUI," have the same level of importance with a value of 0.358, while the "Distinct function" concern has a little lower value of 0.284. For the "Flexibility" sub-criteria, the "Customization" concern has been evaluated as the most important with a value of 0.446, while "Extensibility" has received more consideration than "Compatibility" from the experts. The sub-criterion "Technical

TABLE 2  
The Weights of All Criteria, Sub-Criteria and Concerns in the Hierarchy

| Criteria (Level 2)            | Sub-criteria (Level 3)         | Concerns (Level 4)  |
|-------------------------------|--------------------------------|---|
| <b>Cost</b> 0.261             | IT team – 0.4                  |   |
|                               | IT infrastructure – 0.4        |   |
|                               | Other costs – 0.2              |   |
| <b>Characteristic</b> 0.323   | Usability – 0.322              | Basic function – 0.358<br>Distinct function – 0.284<br>Friendly GUI – 0.358 |
|                               | Technical architecture – 0.054 | Technology – 0.5<br>Operational environment – 0.5                           |
|                               | Reliability – 0.376            | Security – 0.558<br>Stability – 0.442                                       |
|                               | Flexibility – 0.248            | Customization – 0.446<br>Compatibility – 0.245<br>Extensibility – 0.309     |
| <b>Fit with company</b> 0.335 | Industry – 0.351               |   |
|                               | Business goals – 0.414         |   |
|                               | Capabilities – 0.235           |   |
| <b>Vendor</b> 0.081           | Reputation – 0.339             |   |
|                               | Documentation – 0.094          |   |
|                               | Community support – 0.567      |   |

TABLE 3

Determining the Overall Priorities of the Three Alternatives

| Alternative                    |              |              |              |
|--------------------------------|--------------|--------------|--------------|
| Factors                        | SugarCRM     | vTiger       | Compiere     |
| <b>IT team</b>                 |              |              |              |
| 0.104                          | 0.474        | 0.376        | 0.149        |
| <b>IT infrastructure</b>       |              |              |              |
| 0.104                          | 0.346        | 0.436        | 0.218        |
| <b>Other costs</b>             |              |              |              |
| 0.052                          | 0.333        | 0.333        | 0.333        |
| <b>Basic function</b>          |              |              |              |
| 0.037                          | 0.443        | 0.443        | 0.113        |
| <b>Distinct function</b>       |              |              |              |
| 0.030                          | 0.332        | 0.577        | 0.091        |
| <b>Friendly GUI</b>            |              |              |              |
| 0.037                          | 0.490        | 0.315        | 0.195        |
| <b>Technology</b>              |              |              |              |
| 0.009                          | 0.545        | 0.339        | 0.116        |
| <b>Operational environment</b> |              |              |              |
| 0.009                          | 0.441        | 0.358        | 0.201        |
| <b>Security</b>                |              |              |              |
| 0.068                          | 0.413        | 0.327        | 0.260        |
| <b>Stability</b>               |              |              |              |
| 0.054                          | 0.422        | 0.414        | 0.164        |
| <b>Customization</b>           |              |              |              |
| 0.036                          | 0.685        | 0.231        | 0.084        |
| <b>Compatibility</b>           |              |              |              |
| 0.020                          | 0.307        | 0.597        | 0.096        |
| <b>Extensibility</b>           |              |              |              |
| 0.025                          | 0.556        | 0.318        | 0.126        |
| <b>Industry</b>                |              |              |              |
| 0.118                          | 0.425        | 0.348        | 0.226        |
| <b>Business goals</b>          |              |              |              |
| 0.139                          | 0.346        | 0.436        | 0.218        |
| <b>Capabilities</b>            |              |              |              |
| 0.079                          | 0.425        | 0.348        | 0.226        |
| <b>Reputation</b>              |              |              |              |
| 0.028                          | 0.482        | 0.390        | 0.128        |
| <b>Documentation</b>           |              |              |              |
| 0.008                          | 0.485        | 0.393        | 0.122        |
| <b>Community support</b>       |              |              |              |
| 0.046                          | 0.510        | 0.414        | 0.076        |
| <b>Overall priorities</b>      | <b>0.423</b> | <b>0.387</b> | <b>0.190</b> |

Architecture” isn’t highly rated by the experts. Due to rapid changes in IT and strong competition between open source CRM vendors, most of the CRM software offer various ways of quick deployment and integration with other popular open source technologies. There is not big difficulty in choosing what form of service to apply and what technologies to use, so the relative weight of the two concerns “Technology” and “Operational Environment” are equal (0.5).

Among the three sub-criteria of “Fit with company,” “Fit with business goals” has been suggested as the most important issue when choosing a suitable open source CRM software. It has the highest weight of 0.414. The second one is “Fit with industry” with a value of 0.351. The ability of an open source CRM software to match with existing IT conditions and a company resources isn’t too difficult, and hence the weight is 0.235.

Although the “Vendor” criterion has received a low score, “Reputation of vendor” is the second most important thing among the three sub-criteria. It is understandable that the “Community support” sub-criterion has been deemed as the most crucial factor with a relative weight of 0.567, which is moderately higher than the second sub-criterion with the value 0.339. “Documentation” has the lowest priority, with a value of just 0.094.

The final weights of the three alternatives (Figure 3) show SugarCRM with a value 0.423, which is higher than the other two options, namely, vTiger and Compiere. The weight of vTiger is 0.387, which isn’t much lower than SugarCRM’s, while Compiere’s relative weight of 0.190 is much lower compared to the other two alternatives. This result leads us to conclude that SugarCRM is the best CRM software among the three open source CRM software considered. It possibly can be attributed to the various powerful features offered by SugarCRM and the strong investment from the vendor to build high-quality open source software and a well-known brand name to customers, together with the contributions from the community. vTiger also offers a wide range of functionality for users, but there are few factors which are not as good as SugarCRM’s, such as popularity, customer diversity, and investment level for brand image. Compiere has the strength in open source ERP more than CRM, so it is difficult to compete with open source software which only specializes in CRM, such as SugarCRM or vTiger. However, if a company needs to have an ERP and CRM system at the same time, Compiere can be a good candidate for minimizing the expense and getting more benefits. In general, the most important characteristic may be the set of features offered by the CRM software; however, even the most powerful functions are not sufficient if they do not fit well with the company. Hence, the final result would be different from company to company, which depends on the company’s context, state, and situation.

#### 4.3. Sensitivity Analysis

After obtaining the final priorities of the alternatives, a sensitivity analysis (step 7) has been performed to test the responsiveness of the outcome when making changes in the priorities of the major criteria. Relatively small changes in the hierarchy or judgment may lead to different outcomes (Mustafa & Al-Bahar, 1991). By making some minor changes, the practitioner could deeply understand the impact on each alternative according to each criterion and see the overall relationship between



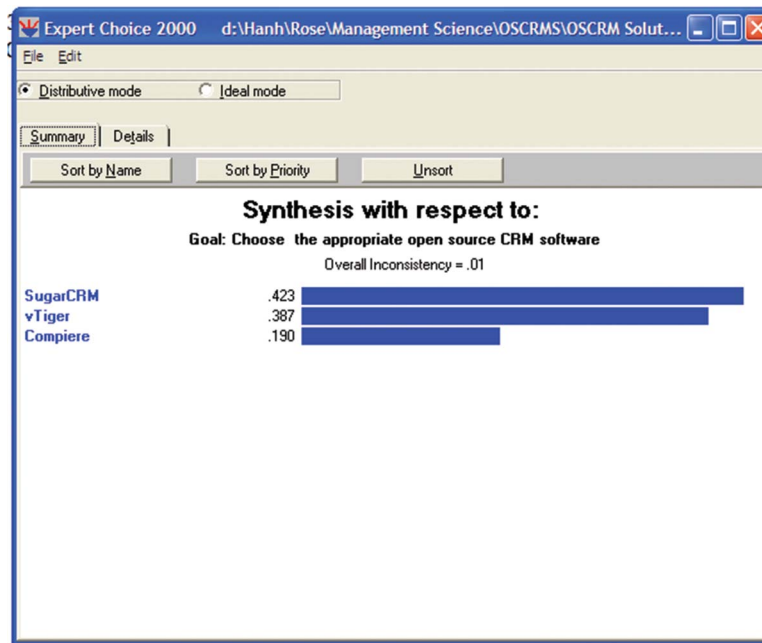


FIG. 3. The final weights of the three alternatives in the model.

alternatives in terms of that criterion. In general, the sensitivity analysis aims to graphically show how the alternatives change with respect to the importance of the criteria or sub-criteria. There are five types of analyses that could be performed using sensitivity-graphs; every analysis has its own function and characteristics. The Expert Choice 2000 software provides the user with the Sensitivity-Graphs function. Thus, the practitioners could easily generate the suitable analysis graph depending on their purpose.

In this article, the gradient sensitivity analysis has been applied. The gradient graph shows the priorities of the alternatives with respect to one criterion at a time, so the practitioners can check the weight of each alternative with respect to a certain criterion which they are interested in. Figure 4 is one example of the gradient sensitivity graph.

The vertical red line represents the current priority of the selected criterion and is read from the X-Axis intersection. The priorities for the alternatives are read from the Y-Axis; it is determined by the intersection of the alternative's line with the criterion's (vertical) priority line. To change a criterion's priority, we can drag the red vertical line to either the left or right; then a blue vertical dotted line showing the new criterion's priority will be displayed (as shown in Figure 4).

The Gradient Sensitivity shows the "key tradeoffs" when two or more alternatives intersect with each other. This is even more important if the intersection is close to the objective's priority. The interesting observation in this research is that the priority lines of the three alternatives don't have any intersection (i.e., they don't intersect with each other with respect to the four main criteria). Although there are changes in the importance

of the major criteria, the ranking of the three alternatives is stable.

The sensitivity analyses have been performed for all the factors in the AHP hierarchy including the criteria, sub-criteria, and concerns. Some factors showed changes in the results, but others remained the same. Due to the large numbers of factors, only a few criteria which have significant responsiveness to the alternatives are presented. Figures 4, 5, 6, and 7 represent the gradient sensitivity for "Cost," "Characteristic," "Fit with company," and "Vendor," respectively. Because SugarCRM dominated vTiger and Compiere in all the criteria mentioned above, it has the highest relative weight value. On the other hand, Compiere is dominated by the other two alternatives with respect to all the elements in the AHP hierarchy.

The sensitivity analyses conducted for the various sub-criteria show different outcomes. For example, SugarCRM is no longer the dominant CRM software when changing some of the sub-criteria. Three sensitivity analyses for the sub-criteria under the main criteria "Cost" indicate the changes in ranking of the alternatives. Figure 8 shows that SugarCRM will be the choice when the relative weight of "IT Team" sub-criteria is larger than 0.4. Figure 9 depicts the contrary, ranking that vTiger dominates the other two when the priority of "IT Infrastructure" sub-criteria is adjusted from 0.4 upwards. On the other hand, there is a balance between vTiger and SugarCRM for the "Other costs" sub-criteria where its priority lines are almost overlapped as shown in Figure 10. These results mean that when the company considers the expenditure for "IT Team" as more important, SugarCRM will be the optimal choice, but if "IT Infrastructure"

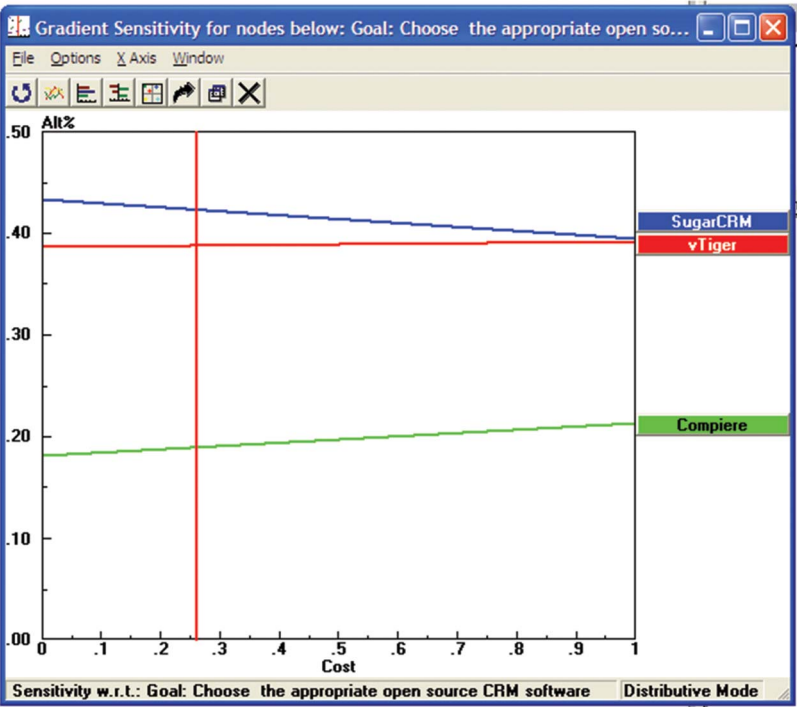


FIG. 4. Gradient sensitivity for main criteria – Cost.

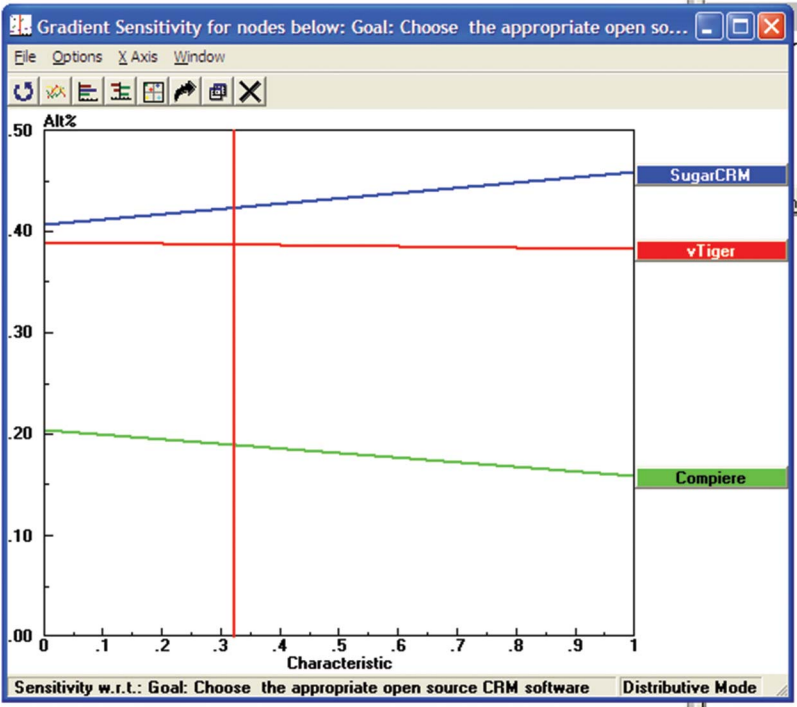


FIG. 5. Gradient sensitivity for main criteria – Characteristic.

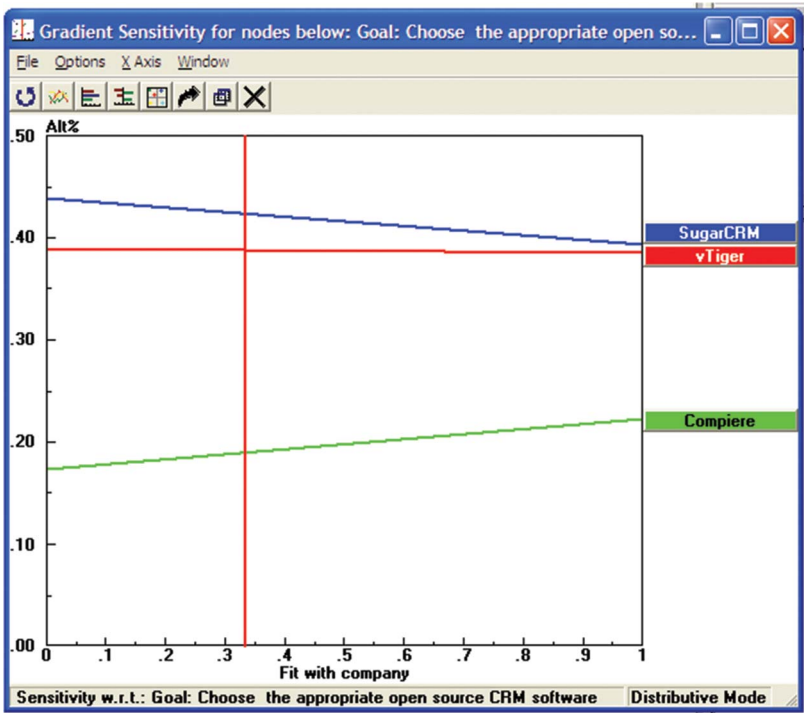


FIG. 6. Gradient sensitivity for main criteria – Fit with company.

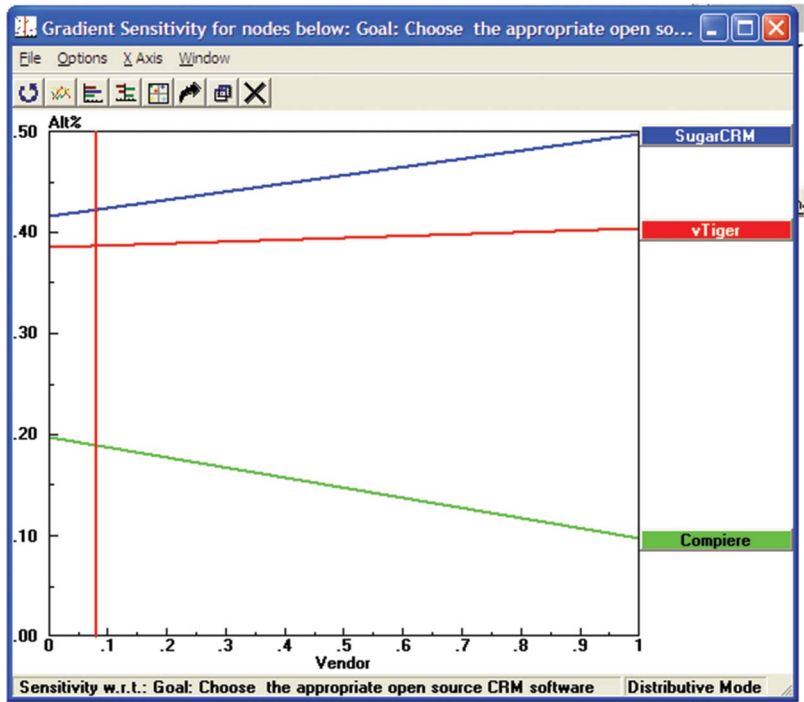


FIG. 7. Gradient sensitivity for main criteria – Vendor.

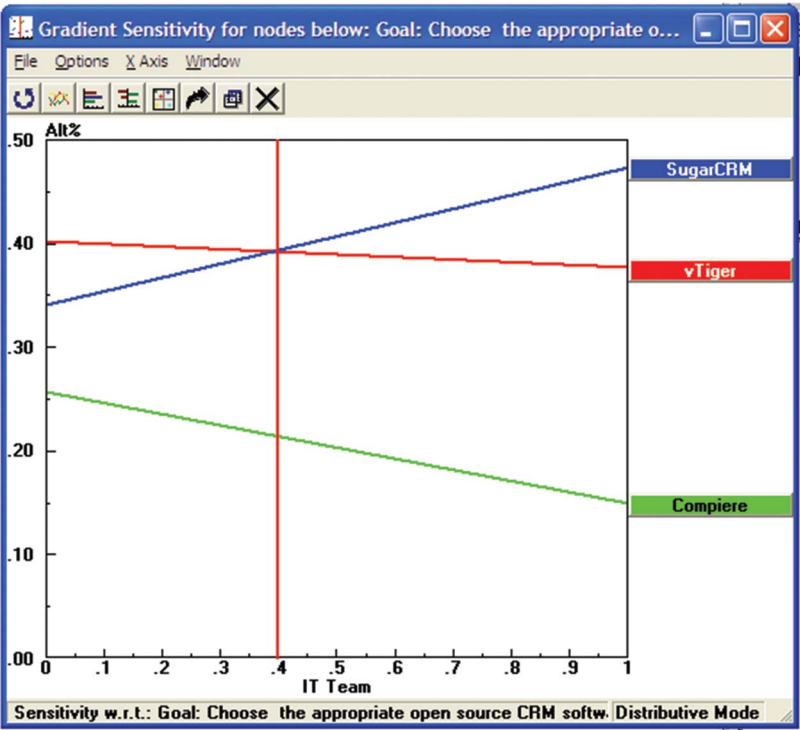


FIG. 8. Gradient sensitivity for sub-criterion – IT team.

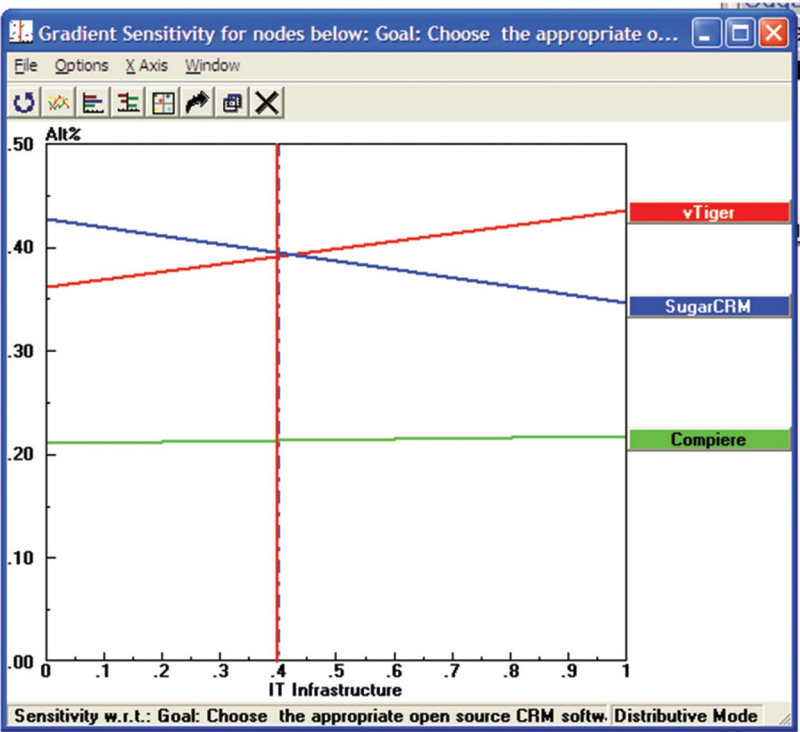


FIG. 9. Gradient sensitivity for sub-criterion – IT infrastructure.



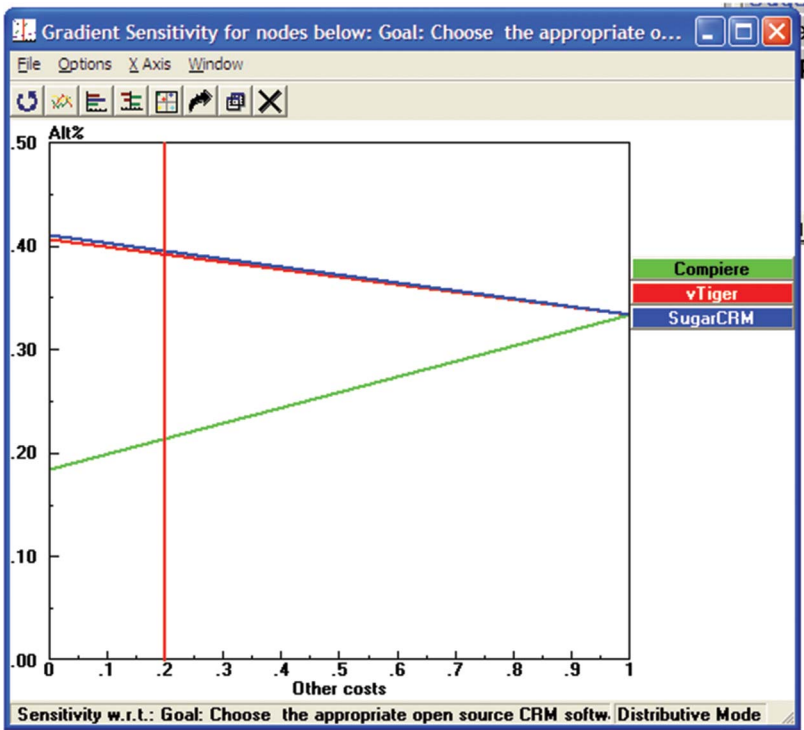


FIG. 10. Gradient sensitivity for sub-criteria – Other costs.

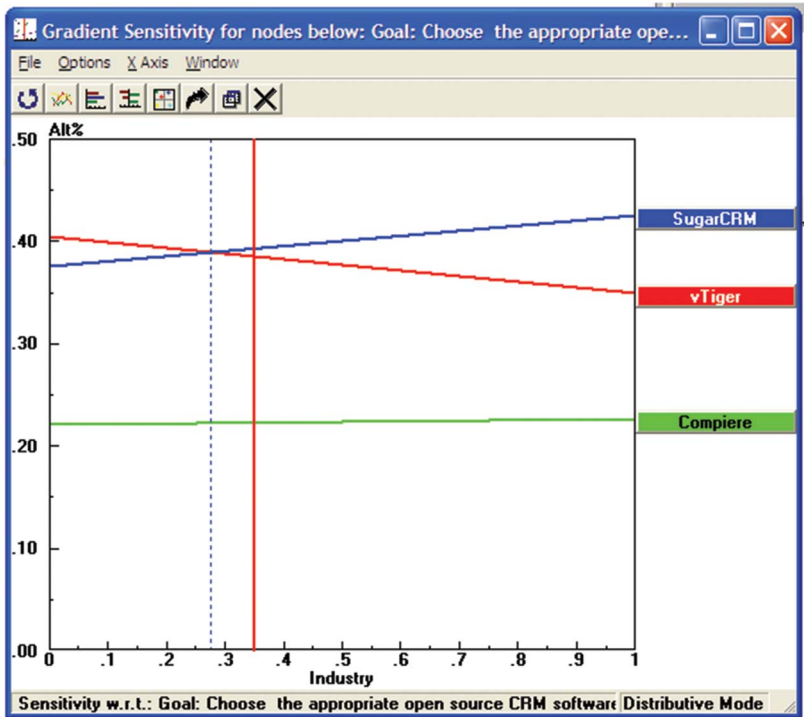


FIG. 11. Gradient sensitivity for sub-criteria – Industry.

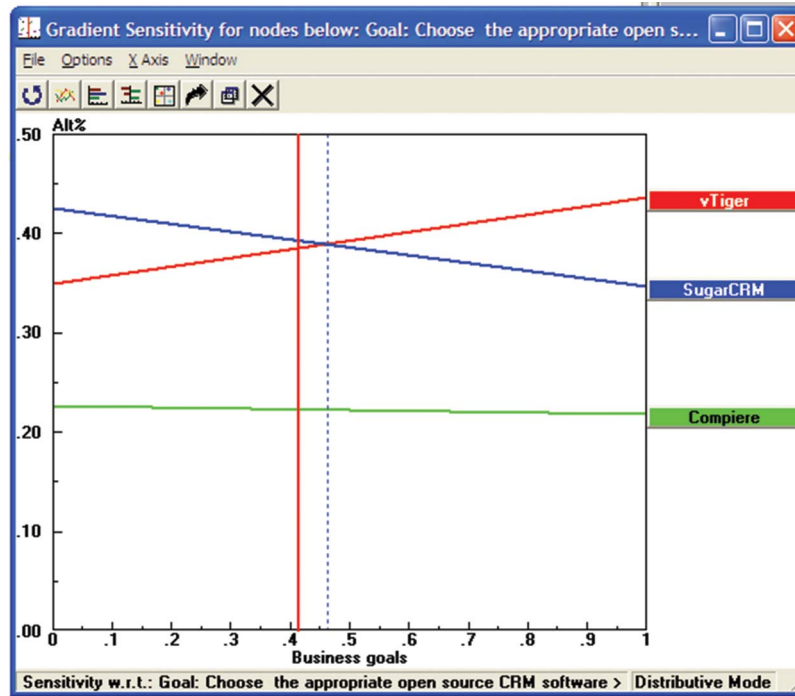


FIG. 12. Gradient sensitivity for sub-criteria – Business goals.

is considered more important, then the appropriate choice is vTiger. This choice will help the company achieve more cost savings. With respect to other costs, vTiger and SugarCRM will likely require similar expenses from the adopter.

Two additional sensitivity analyses were performed for “Industry” and “Business goals,” which are the sub-criteria under “Fit with company.” Figure 11 indicates that vTiger is the most favorable choice when the relative weight of “Industry” is smaller than 0.3; if it is greater than 0.3, SugarCRM becomes the optimal alternative. This represents the wide range of industry that SugarCRM can be used in. According to Figure 12, in case the priority of “Business goals” is higher 0.45, vTiger dominates the others and will be the choice. However, when the priority is adjusted downwards from 0.45, the appropriate selection will be SugarCRM.

## 5. CONCLUSIONS

In this article, an AHP-based multi-criteria decision model has been developed, which provides a holistic consideration in the selection of open source CRM software. This model has been applied to select what is probably the best open source CRM software in the market today. With these two activities, this article has contributed to not only the academic community but also the practitioner community. The results of this research have great implications for the industry in terms of open source CRM software selection. The contributions of this article are elaborated below.

First, the CRM selection hierarchy presented in this article is a suggestive model for CIOs or managers when they are faced with the open source CRM software selection problem. It has been developed with great care by considering all the relevant literature. We have systematically identified the important factors and clearly defined them. Then we developed the rationale for these factors and built consistent hierarchies to take into account the concerns of the recent open source CRM software deployment from various dimensions. Moreover, based on the current literature, suitable variables were selected, analyzed, and synthesized to develop appropriate criteria. We developed precise operational definitions based on a thorough analysis of relevant studies.

Second, the available CRM hierarchy could be a good reference point for the first step of determining what criteria should be considered in selecting an open source CRM software. The practitioners can use this model to evaluate their open source CRM software portfolio by replacing the alternatives with their specific alternatives. They can customize the developed model to create a new model which is more appropriate for their particular set of requirements by adding additional criteria, sub-criteria, or attributes. By providing the hierarchy for open source CRM software selection, we hope the readers can save time and effort in examining the important aspects of the CRM software and selecting the appropriate CRM software for their organization.

Third, by conducting an empirical study and applying the developed CRM selection hierarchy, the article recommends

some prominent open source CRM software for the readers. The AHP method has been applied to identify which is the best open source CRM software among the three alternatives considered, namely, SugarCRM, vTiger, and Compiere, with the feedback from experts. Based on the final result, SugarCRM is likely the best open source CRM software. CIOs and managers can consider SugarCRM as a good candidate for their CRM software needs. Through experts' evaluation of the three specific alternatives mentioned above, the readers can gain a closer look at SugarCRM, vTiger, and Compiere in terms of their functionality, features, strengths, and weaknesses. This article has attempted to provide the necessary and meaningful information with respect to these three open source CRM software.

Fourth, the AHP methodology has been shown to be a useful technique to solve the problem of how to choose a suitable open source CRM software among many available products. It shows the possibility of applying this powerful decision-making technique as an efficient tool for other problems as well. With the effective support from the AHP software, particularly, *Expert Choice 2000* used in this article, practitioners can easily use the AHP model for not only decision-making but also any issue in any field, such as resource allocation, conflict resolution, planning, and so forth. They only have to construct the AHP hierarchy for their problem domain and perform the pairwise comparison; all the complex and lengthy computations will be done by the AHP software quickly and accurately. They can use the sensitivity function of the AHP software to conduct more analysis regarding the impact of a particular criterion on the final result. For researchers, besides gaining more knowledge about open source CRM software, they could apply scientific methodologies such as AHP or ANP to emerging domains such as social CRM, cloud CRM, or other software, technology, and non-technology areas. Moreover, they can conduct future research by utilizing the findings from this article—for example, developing a new version of the AHP CRM hierarchies, or conducting a case study of open source CRM deployment for a specific company by applying the framework developed in this article. These activities will help improve the validity, generalizability, objectivity, and reliability of our research.

Nowadays, open source CRM software is attractive for most companies, especially small and medium sized enterprises. In any business, CRM helps the organization in a lot of ways, both in terms of being able to deliver more value to customers and also gain more from them. So, the issue of how to select the appropriate open source CRM software to adopt is essential and worthwhile to study. From this research, the readers, specifically CIOs and managers, could use our proposed approach to select the appropriate open source CRM software which fits with not only their company's business goals but also their requirements and capabilities. This will enable them to exploit the benefits of the open source CRM software to the fullest.

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