Abstract. The proliferation of ERP systems naturally leads to an intriguing question of products classification. In this paper, a framework for analyzing ERP systems is proposed. This framework includes various IT infrastructures that can be incorporated in the n-tier architecture. By using cluster analysis, different groups of ERP systems are classified to verify the correctness of the framework. The results may be useful for ERP vendors to improve their products strategy and help companies to evaluate most suitable ERP products to satisfy their requirements.

Keywords. Enterprise Resource Planning (ERP), Classification Framework, Cluster Analysis, N-tier Architecture

1. Introduction

Information technology has been viewed by enterprises worldwide as vital tools in improving efficiency and competitiveness. In the last decade, many companies turning to use information systems usually known as enterprise resource planning (ERP) systems to respond to competitive pressures and market opportunities quickly, to make product configuration flexibly and to reduce inventory obviously [4].

ERP systems are integrated information systems that support value-added processes of enterprises. Based on modular software structure and centralized database, information flows in manufacturing, finance, sales, distribution as well as human resources processes can be integrated in real time. The ERP systems have become one of the largest IT investments for many companies during the 1990s [5]. ERP systems are not only used by large companies but also penetrated into small and medium companies [12].

It is expensive and time consuming for companies to implement ERP systems [6]. The companies can take many years to implement ERP systems, and cost $10 millions for a moderate size company and over $100 millions for a large international enterprise [17].

Since ERP systems are critical to companies and expensive to acquire, many studies have been devoted to find the recipe for successful implementation. Among other important factors, product selection has been singled out by many research reports. For example, Jason and Subramanian points out that in order to implement and use ERP system successfully, companies have to select right ERP packages to match its requirement [14]. Esteves and Pastor also emphasize that the selection of ERP products and consultants is an important step in the proposed ERP Life-Cycle framework [10]. Al-Mashari et al. also list correct ERP package selection in the critical successful factors of ERP projects [2].

Currently many ERP systems are available in the market. In Taiwan along, there are 61 ERP vendors, and the CIBRES listed approximately 1500 different ERP solutions provided by a variety of vendors in 2000 [3]. These products can differ from each other very much. The differences play an important role in software/vendor selection. The vast number of vendors and the difference of functionality and architecture have put much pressure on the system selection processes. Although software selection is important, to the best of our knowledge, no academic work has been devoted to provide formal framework to compare and contrast the characteristics of ERP systems. Such a framework should provide evaluation items come with theoretic supports, be able to distinguish products with different functionality, and it should be applicable to most ERP systems.

In this paper, a software architecture evaluation framework for ERP systems based on client server technology, browser based computing, system integration capability and support of globalization is proposed. To verify the quality of the framework, several ERP products that are widely used in Greater China...
area are evaluated with the functional list designed with the framework. The results show that the framework can be applied to a wide range of software and can reasonably distinguish products designed with different complexities.

2. Methodology

The research involves four major steps to establish and verify the ERP analysis framework.

1. Identification of the simplified ERP analysis framework. It includes collection of attributes and functions for developing the analysis framework. The research includes information technology attributes, production functions and finance functions currently. Then the simplified ERP analysis framework of ERP systems showing the IT infrastructure, ERP modules and interface to external systems will be presented.

2. Identification of ERP vendors from the Market Intelligence Center (MIC) of Information Industry Institute (III) in Taiwan and the Internet search. For it, the ERP software vendors, products, and descriptions will be identified and only some, but not all ERP products will be surveyed in this research. The ERP vendors must have branch offices in Taiwan and the Mainland China at the same time. These vendors include international and local ERP vendors.

3. The function list is sent to the selected ERP vendors. The data filled by vendors are verified with independent experts or users in customer sites. Only the reports that have consistent view from both parties are reserved for clustering analysis.

4. Identification and analysis of the IT attributes contained in the ERP products. Each key IT attribute has a variety of sub-features or capabilities. These attributes of different ERP products were identified and analyzed. By evaluating the relationship among the aggregations of ERP attributes using cluster analysis, the different groups of ERP products might be identified and described.

3. A framework for analyzing ERP systems

Because ERP systems are continuously evolving in terms of technology and functionality [16], in this paper both functions and attributes are used to be as the taxonomic characters to classify ERP systems.

A simplified framework for analysis of ERP systems shows the IT infrastructure, major ERP modules, and their relationships with some external systems by interfaces as shown in Fig. 1. The major modules of ERP systems may include finance, manufacturing, human resources, sales and marketing, and so on [2,7,8]. After ERP having implemented systems successfully, many companies are considering and implementing various extensions to the systems. The extendable external systems could include supplier chain management (SCM), customer relationship management (CRM), ebusiness or e-commerce solutions (B2B and B2C), data warehouse (DW), data mining (DM), business intelligence (BI), knowledge management (KM), and so on [13,17,18,19,25,27]. By integrating ERP system with these external systems, company can improve the relationships with suppliers and customers and provide competitive advantage for the organization. According to Sprott [23], ERP system can integrate with others applications by integration standards (such as XML, RosettaNet) and component interface protocols (such as CORBA, COM+ and EJB). For others systems to retrieve and store data in the ERP system, there are three most used methods from the experiences of professional consultants, of ERP vendors and consulting companies. The three integration methods include predefined programs, temporary data files and read/write tables in database directly. In this paper, the focus will be on IT infrastructure that supported the ERP system operation.

![Figure 1. Framework for analyzing ERP systems](image-url)
into reality by applying software systems to links activities (functional areas) in a client/server architectural environment [1,11,20,24]. In the viewpoint of IT infrastructure, ERP systems have three components: client/server system, enterprise-wide database as well as the application modules [28]. User interface is one characteristic of the client/server model [21], which is typically a graphic user interface (GUI).

According to Sinha [22], there are following key issues that must be considered for a client/server system:
- **Client:** (1) workstation operating system, (2) hardware constraints, (3) connectivity constraints, (4) object-oriented design, (5) GUI, (6) division of responsibility.
- **Server:** (1) scalability, (2) server interface, (3) gateway to mainframe, (4) disk space, (5) security and access control, (6) backup, recovery and logging, (7) fault tolerance and uninterrupted power supply, (8) performance and system management, (9) internetworking.

Because information technologies have made progress on hardware and software continuously, some key issues have been excluded from this paper, e.g., hardware constraints, disk space and internetworking. Some issues that are not related to ERP systems have been neglected also, e.g., OO design, fault tolerance and UPS. The gateway to mainframe issue has been revised to gateway to external systems based on above framework.

Information technologies have evolved from client/server computing to the Internet era. The system architecture extends to 4-tier web-based architecture [9]. The web-based architecture consists of four layers: client, web server, application server and database server. Owing to the development of mobile technology, the mobile devices can be used to access information systems [15]. Users may connect to ERP systems by browsers and mobile devices so that the ERP systems can be integrated to the supply chain management (SCM) system, customer relationship management (CRM) system, and so on.

In addition to information infrastructure based on n-tier architecture, Davenport [7] pointed out that ERP systems should include some specific technical or business-enabling features. These business-enabling features consist of data ownership, procedures, transaction visibility, global or multilocal, data management, modifications and best practices orientation. The data ownership feature is more likely a management issue rather than IT responsibility and data management feature is categorized to database server attribute. Hence, this paper does not include these two business-enabling features. From above research the IT attributes will be studied under the framework given by the Fig. 2.

![Figure 2. Framework of IT attributes](image)

### 4. Data collection and verification

A total of 61 ERP software vendors were identified from the Market Intelligence Center (MIC) of Institute of Information Industry (III) in Taiwan. This vendors list consists of major ERP vendors in Taiwan and well-known international ERP vendors which have branch offices or agents in Taiwan. Among the 61 companies, 32 are taken away from the list since they do not have branches to operate in Mainland China or Hong Kong. Phone calls were made to the left 29 companies to invite them to join the research. 25 out of the 29 companies agreed to review the forms derived from analysis framework.

After reviewing the framework, 16 companies do not express their interest to attend the research. After one month of intensive communication, 9 out of the 25 companies return their forms. Such a low return rate we believe is caused by two problems. One is that the framework may reveal that their IT attributes have a lot of room to grow. The second one is because the framework requires experts to fill out the form and they are...
extremely busy during the intensive communication period. However no company has complained that their products cannot be analyzed by the framework.

To assure that the data filled are accurate, telephone interviews are also performed to make sure the experts filling the data fully understand the questionnaire. To verify the data, the same form is also used to interviewed customers of the companies or experts who do not work for the vendors. Three out of the nine returned questionnaires cannot be confirmed by such a verification procedure either due to customers did not use the latest versions or the experts are out of the country when the survey was performed. Hence, the framework verification phase successfully obtains the analysis reports of six products from six companies. Their characteristics are listed in Table 1.

### Table 1. Characteristics of the ERP products under analysis

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Year of founded</th>
<th>Major market area</th>
<th>Company profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1982</td>
<td>Taiwan and China</td>
<td>The largest ERP vendor in Taiwan</td>
</tr>
<tr>
<td>B</td>
<td>1994</td>
<td>Taiwan and China</td>
<td>Aggressively expanding ERP vendor</td>
</tr>
<tr>
<td>C</td>
<td>1977</td>
<td>Worldwide</td>
<td>The largest ERP vendor in U.S.</td>
</tr>
<tr>
<td>D</td>
<td>1987</td>
<td>Taiwan and China</td>
<td>The second ERP vendor in Taiwan</td>
</tr>
<tr>
<td>E</td>
<td>1972</td>
<td>Worldwide</td>
<td>The largest ERP vendor worldwide</td>
</tr>
<tr>
<td>F</td>
<td>1994</td>
<td>Taiwan and China</td>
<td>Aggressively expanding ERP vendors</td>
</tr>
</tbody>
</table>

5. Analysis of ERP systems

The IT attributes include client, web server, application server, database server, system architecture and business-enabling functions. These attributes support the infrastructure requirements for ERP systems from the aspect of client-server architecture.

5.1 The result of the analysis

The features associated with the IT attributes for all the six ERP products are shown in Table 2. The values of each column mean the number of features for each ERP products supported. The number contained within parentheses is the total number of features surveyed for each IT attribute. There are in total sixty-four features that categorized as six IT attributes including client, web server, application server, database server, system architecture and business-enabling features.

### Table 2. Features associated with the IT attributes

<table>
<thead>
<tr>
<th>IT Attributes</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client (14)</td>
<td>7</td>
<td>12</td>
<td>6</td>
<td>13</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Web server (6)</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Application server (21)</td>
<td>14</td>
<td>9</td>
<td>21</td>
<td>16</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Database server (10)</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>System architecture (3)</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Business-enabling features (10)</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Total (64)</td>
<td>33</td>
<td>32</td>
<td>51</td>
<td>38</td>
<td>56</td>
<td>21</td>
</tr>
</tbody>
</table>

Combined the total IT attributes, the product E supports most of the features for IT attributes. For local ERP products, the product D supports most of the features for IT attributes. There is no huge difference between the two international ERP products about IT attributes. But for the four local ERP products, they have bigger differences among them. The comparisons of six ERP products for all the six IT attributes are shown in Fig. 3.

### Figure 3. Comparisons of six ERP products based on six IT attributes

5.2 Cluster analysis

The different ERP systems can be placed to dissimilar clusters by using the cluster analysis. The goal of cluster analysis is to classify the ERP systems into clusters. In such a way, the ERP systems with similar number of attributes or functions are placed in the same cluster. The result of the survey is clustered with complete linkage methodology to examine if products under survey can be naturally grouped. The result of the cluster is to verify if the analysis framework can reasonably distinguish products. In this research, the agglomerative hierarchical clustering is used to analyze the IT attributes of ERP systems. All the surveyed results are analyzed by SPSS 10.0 software and used complete-linkage algorithm. The Fig. 4 shows the results of cluster analysis for six ERP systems based on IT attributes.
From Fig. 4, we can naturally cut the ERP systems into two groups by setting the distance at 15. The two different groups are:

- Group I: international vendors, the top leaders in ERP worldwide market.
- Group II: local vendors, the top ERP vendors and highest market share on small and medium enterprises in Taiwan.

Among the local ERP vendors, the four companies can be divided into two subgroups by setting the distance at 10. The major reason is that only one ERP system supports web architecture while the others not.

The result matches products’ general image and thus implies that the analysis framework can reasonably distinguish products.

6. Conclusions and future works

Product selection has been singled out by many research reports. After checking some local and international renowned ERP software products, the similarities and dissimilarities of ERP systems can be found. The classification framework developed in this paper can help the software vendors to improve their ERP products strategy. On the other hand, for the ERP user companies, this classification framework will support them in choosing suitable ERP products considering their requirements and existing IT architecture. The NESAF developed in this paper can help companies to select most suitable ERP system according to their requirements and existing IT architecture. Considering the future growth of system and integration with other systems, the framework can also help to determine which kind of ERP solution is most flexible.

The framework consists of six major IT attribute categories to classify ERP products. These attributes include client, web server, application server, database server, system architecture and business-enabling features. The framework covers client/server technology, browser based computing, integration to external systems and the support of business enabling feature.

The framework has solid theoretic foundation since it based on client/server architecture [22] and web base computing [9] to develop system attributes and global business requirement to derive business enabling feature [7]. The clustering analysis in the verification phase implies the framework can reasonably distinguish products. During the process of collecting ERP product analysis reports, we have not found any company complaining that the framework is not suitable to evaluate their products. From the friendly response, we have strong confidence that the framework can be applied to major ERP systems.

The study tries to establish the IT attributes analysis framework of ERP systems. However, as the discussion in section 1 shows, ERP has many strong functional aspects in handling business processes. In the future work, we suggest at least manufacturing and financial analysis should be added to the analysis framework since financial modules have the highest installed priority [17] and ERP systems have the highest penetration rate in manufacturing industries [26].

7. Acknowledgements

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8. References

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