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# An empirical investigation of six levels of enterprise resource planning integration

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ABSTRACT

The purpose of this research is to propose a six-level ERP integration model and to empirically investigate if each of the six levels exists. The six levels are system-specification, system–user, islands-of-technology, organizational, socio-organizational, and global integration. Empirical data were collected by using a large-scale survey of ERP professionals. We conducted various validity and reliability tests to confirm the proposed theoretical framework. Using partial least squares (PLSs) analysis, the results of the investigation confirmed the existence of the six levels of ERP integration. The results of the investigation have implications for research and practice.



## 1. Introduction

Running an effective business in a global economy requires attention to a wide array of important challenges: globalization, integrating business processes, automating business processes, sharing data and business practices, changing customer demands, reduced product life cycle, real time access to information, increasing market diversity, higher knowledge intensity, operational transparency, up-to-the-minute on-line transactions, improved coordination, and rapid changes in information technology (IT) (Madnick, 1991; Nah & Lau, 2001; Schlichter & Kraemmergaard, 2009; Scott-Morton, 1991; Soh, Kien, & Tay-Yap, 2000). One approach to dealing with these challenges is enterprise resource planning (ERP), which is an often used strategy for achieving integration (Burns, Jung, & Hoffman, 2009; Mathew, 2006; Mendoza, Perez, & Griman, 2006). It provides an integrated, comprehensive, updated, and realistic view of a company's operations (Scalle & Cotteler, 1999; Sheu et al., 2003). Evidence suggests that ERP improves company productivity and performance (Chalmeta, Campos, & Grangel, 2001; Hendricks, Singhai, & Stratman, 2007; Jones & Kochtanek, 2004; Laframboise, 2005; Mabert, Soni, & Venkataramanan, 2000; Ward, 2006) and that seventy percent of the Fortune 1000 companies have used it (Bingi et al., 1999). In 2004 the estimated market growth of ERP was $60 billion (Callaway, 2000; Mabert et al., 2000). A report by AMR Research estimated that the market for ERP software will grow from $28.8 billion in 2006 to $47.7 billion in 2011. The growth is fueled by the adoption of ERP systems by small and medium size companies (Jacobsen, Shepherd, D'Aquila, & Carter, 2007).

Implementing ERP is expensive (Jones & Young, 2006; Sanchez & The SOA approach to integration, 2006; Mabert, 2000) and involves considerable technical and financial risks, but the expected financial and business returns are very high. Nonetheless, business executives are challenged to justify ERP expenditures because the financial benefits are often uncertain (Davenport, 1998; Deutsch, 1998; Sheu et al., 2003; Wailgum, 2005). Therefore, it is important to understand the risks of using ERP as an enabler of integration because it has not always lived up to its expectations (Mabert, 2000; Wailgum, 2005). Two reasons for ERP disappointment are that it disrupts the business processes (Kremers & Van Dissel, 2000; Scheer & Habermann, 2000; Soh et al., 2000) and threatens the corporate culture (Hasselbring, 2000; Ward, 2006). ERP disappointment (Wailgum, 2005; Gattiker, 2002; Saccomano, 1999; Schulz, 2000; Songini, 2005; Scheer & Habermann, 2000; Markus & Tanis, 2000); implementation failures are well documented (Wailgum, 2005; Sheu, 2003; Davenport, 1998; Deutsch, 1998).

We define integration as the collection of IT-related components, including systems and users, to create a unified and seamless whole. When the components are optimally combined, they perform in concert to support a company's mission and fulfill its goals and objectives (Grant, 1995). We take it for granted and we assume that ERPs and other enterprise systems lead to enterprise integration. According to Bakar (2003), integration adds quantitative and qualitative benefits to companies. A primary purpose of enterprise systems is to integrate all the business functions within

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a company (Schlichter & Kraemmergaard, 2009), but there is no empirical evidence to support these claims. It is taken for granted that ERP systems achieve integration, but how do we know that integration exists if we cannot measure it? There are various levels of integration, so what level of integration can we expect from an ERP system? These are important questions that could be answered from empirical evidence confirming the existence of integration and the role ERP plays in this regard. To address the more challenging aspects of integration we first need to investigate if integration exists. Therefore, our research objective is to investigate whether or not integration exists. This is accomplished by testing the existence of the six levels of enterprise integration. The six levels were developed by analyzing the strengths and weaknesses of prior integration models. The weaknesses of prior models inspired the proposal of a new integration model better suited for this investigation. The proposed model is then empirically tested.

To accomplish our research objective, we first propose a six-level model of ERP integration. There are various studies that have looked at different levels of integration, but there has been no empirical study that specifically focuses on the dimensions of ERP integration. We then discuss how each integration level builds upon lower levels in a manner similar to a stage growth model. Next we conduct empirical investigation to find evidence of enterprise integration by testing the existence of the six levels using survey data from ERP professionals. We used PLS analysis to investigate the different integration dimensions. Finally, we explain the research methods used in the study, and discuss the results and future research questions.

## 2. Literature review

### 2.1. Integration

Five models of integration are discussed in the literature, and each has strengths and weaknesses. The first model (Mathew, 1986) originated in manufacturing and achieves integration by linking management information systems (MISs), computer-aided design (CAD), and computer-aided manufacturing (CAM) using an integrated database. MIS was used for scheduling and control, distribution management, accounting, and finance. CAM was used for process planning and control, process automation, and shop floor management. CAD was used for conceptualization, analysis, visualization, and detailing. This is a limited view of integration because it assumes that integration is limited to three types of information systems (ISs) and ignores other types of IS (CSM, CRM, ERP, DSS, EIS, DSS, etc.). The view espoused in the definition is focused exclusively on manufacturing and ignores non-manufacturing companies. It fails to address other aspects of integration such as global integration, which links companies that are geographically dispersed; business function integration, which fosters collaboration among departments; integration between users and technology, integration that enables a common or shared vision between collaborating departments or companies, and strategic integration used to accomplish company strategy.

The second model (Bullers & Reid, 1990) defines integration as the linking of four major types of information systems (ISs) – Electronic Data Processing (EDP), MIS, decision support systems (DSSs), and expert systems (ESs) – with Computerized Manufacturing Systems (CMSs). Linking these four systems involves four types of integration: (1) horizontal integration, (2) vertical integration, (3) temporal integration, and (4) physical integration. Horizontal integration aids coordination among the manufacturing functions while vertical integration enables access to information for decision-making. Temporal integration enables the use of historical information for future planning efforts while physical integration links geographically dispersed facilities. This definition suffers from similar weaknesses as the previous model by neglecting user integration, global integration, and external integration such as supply chain management (SCM) and customer relationship management (CRM). Unlike the first model, manufacturing related integration is ignored.

Burbidge, Falster, Riis, and Svendsen (1987) define integration as the linking of internal business functions across functional boundaries such as marketing, production, and manufacturing. This concept of integration originated from a need to share goals and information, and to facilitate communication and consultation. This is an internal view of integration because it ignores external and global integration. Concepts like global integration, supply chain integration, customer relationship management integration, and strategic integration are missing. External characteristics of integration that link companies and their operations to the external environment are ignored.

Meredith and Hill (1990) discuss four types of integration for cost justification of manufacturing equipment. Level-1 integration consists of stand-alone computer hardware, often controlled by programmable controllers such as numerically controlled machines. Level-2 integration consists of multiple pieces of Level-1 equipment connected in a cellular configuration to perform multiple tasks on a family of parts. Level-3 integration links manufacturing cells of Level-2 integration into computerized information networks. Level-4 is full integration that links the manufacturing function and all of its interfaces through extensive networks. While we do like the concept of levels of integration, we do not think the integration levels presented by Meredith and Hill go far enough to represent a wider view of integration because they focus exclusively on manufacturing and ignore non-manufacturing. It is an internal view of integration that ignores external characteristics of integration like SCM, CRM, global integration, and strategic integration.

Truman (2000) defines integration as being related to electronic exchange environments, particularly the business-to-business, and Electronic Data Interchange (EDI) system environment. It involves two types of integration: interface integration and internal integration. Interface integration is integration between EDI and internal systems of the organization. Internal integration is integration between the organization's internal systems. This view is limited because it focuses exclusively on EDI and neglects all other characteristics of internal and external integration. A summary review of the integration models is shown in Table 1. The weaknesses in Table 1 were identified by reviewing the literature to learn about different types of integration. This knowledge was used to analyze the comprehensiveness of all five models. The more types of integration a model has, the fewer weaknesses it exhibits. For example, MIS, CAD, and CAM do not address global integration, business function integration, and external integration between firms, and hence the need for enterprise systems likes ERP.

### 2.2. ERP Integration

In the late 1980s ERP emerged as a derivative of material requirement planning (MRP) systems that convert master production plans into detailed requirement schedules of raw materials and components. MRP-II, an enhanced version of MRP, improved manufacturing system integration by sharing data from several different functional areas, including sales, production, inventory, finance, and accounting. Today's ERP applications are rooted in MRP-II (Laframboise, 2005; Markus & Tanis, 2000) but differ in many ways. They commonly run on client/server architecture instead of MRP-II mainframe-based technology. ERP applications support an even broader range of business processes and

**Table 1**
Literature and weaknesses of integration.

| Models of Integration | Strengths of the Model | Weaknesses of the Model |
|---|---|---|
| Mathew (1986) | Focuses on MIS, CAD, CAM, and integrated DB | Ignores integration between functions, integration between firms, global integration, user integration, temporal integration; shared vision; strategic integration |
| Burbidge (1987) | Focuses on inter-business function and intra-business function integration | Ignores integration between firms, global integration, user integration, temporal integration; shared vision; strategic integration |
| Bullers et al. (1990) | Focuses on EDP, MIS, DSS, ES, CMS, horizontal, vertical, temporal and physical integration | Ignores integration between firms, global integration, user integration; shared vision; strategic integration |
| Meredith et al. (1990) | Focuses on integration of standalone hardware and linking islands of technology | Ignores integration between firms, global integration, user integration, temporal integration; shared vision; strategic integration |
| Truman (2000) | Focuses on B2B-EDI, interface integration, and internal integration | Ignores integration between firms, global integration, user integration, temporal integration; shared vision; strategic integration |

functional areas than MRP-II, and they are used in a variety of industries including manufacturing.[1]

The expected tangible and intangible benefits of implementing ERP include inventory reduction, personnel reduction, improved order management, reduced longer term IT costs if implemented successfully, improved responsiveness to customers, standardization of computer platforms, and global sharing of information. The primary strategic advantage and the ultimate goal of ERP is enhanced system integration (Bingi et al., 1999). Improved business process integration is a precondition for realizing additional benefits that organizations expect to achieve through ERP implementation.

We define integration as a collection of related components – computer information systems, manufacturing systems, engineering systems, production systems, management systems, distribution systems, financial systems, accounting systems, and users – to form a unified and seamless whole. These components, when optimally combined, should perform in concert to support and achieve an organization's goals and objectives (Grant, 1995). Entire organizations, not just the manufacturing function, should be well integrated if they are to successfully compete in the global economy. The timely information required for collaboration, coordination, synergy, control, decision-making, and the management of organizations will not be realized if companies avoid taking a holistic approach to integration. ERP, when used effectively, can enhance enterprise integration.

The definition of integration is often taken for granted. This has led to conflicting claims by companies of having achieved integration through ERP, but with very different performance outcomes. The problem resides in an older industrial mindset of many managers, namely, the "technology imperative," which views technology as an exogenous driving force that dictates the behavior of individuals and organizations (Markus & Robey, 1988). Unfortunately, this technology-imperative mindset no longer works in highly uncertain and competitive post-industrial environments. Clemons and Row (1991) argued that when identical technology is available and applications can be easily duplicated, sustaining technological advantage will not come from ownership, but from how effectively it is used. ERP is not a panacea for all performance problems, but rather an enabler for business process integration.

An examination of companies that implemented ERP reveals that they are at different levels of integration. Main (1990) questioned whether some firms have achieved it. He believes there is no universally accepted definition and objective measures of integration. Multiple definitions, subjective measures, and their concomitant interpretations are testament that integration is neither static nor absolute. Therefore, we need better definitions of integration and a framework that accommodates multiple levels of ERP integration. This will aid the understanding, managing, and implementing of ERP. We propose an integration model with six levels of integration found in industry. The proposed model provides a vehicle to better explain the stages of integration growth (i.e., levels of integration) exhibited in industry and discussed in the literature. It also provides a measure of objectivity for future discussions on ERP integration. In the empirical study, we test the relationships between the six levels of ERP integration.

## 3. Six levels of ERP integration

The weaknesses of the models discussed earlier can be categorized into two areas. First is the limited view espoused by models that restrict integration to either internal or external characteristics of the organization but not both. A truly integrated company has both types of integration. Second, integration should not be limited to either manufacturing or non-manufacturing companies but should be broad enough to be applicable to both. These weaknesses motivated the need for a more robust and encompassing model of integration. The Meredith and Hill (1990) model inspired us to propose a new model because it was consistent with the stage growth model and could be applied to both manufacturing and non-manufacturing. Meredith introduces the idea of levels of

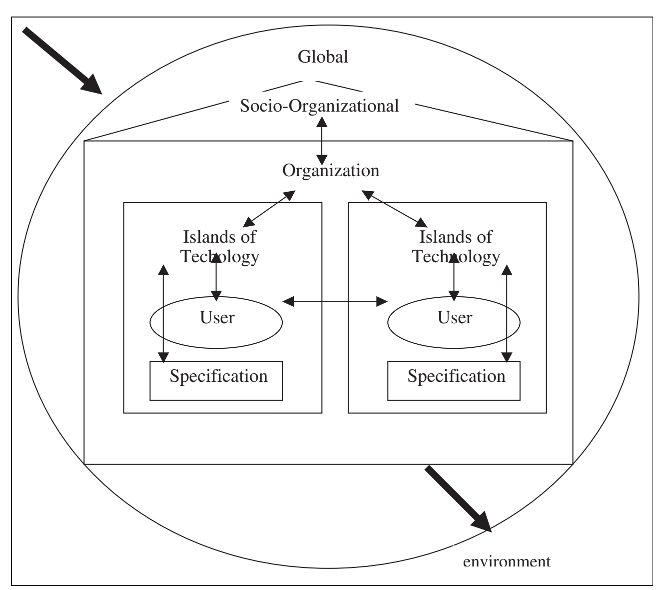


**Fig. 1.** Six levels of ERP integration (Grant & Tu, 2005).

[1] A typical ERP application supports cross-functional business processes by linking the following six primary business functions: 1. Accounting and controlling; 2. HR management; 3. Production and materials management; 4. Project management; 5. Quality management and plant maintenance; 6. Sales and distribution (Callaway, 1999; Ward, 2006). Recently, ERP vendors are branching into new areas such as Supply Chain Management (SCM), E-commerce, Customer Relationship Management (CRM) and Business Intelligence (BI) (Callaway, 2000).

**Table 2**
Types of integration at each of the six levels.

| Levels of integration | Types of integration | Related studies |
|---|---|---|
| Level-6: global integration | Internal horizontal<br>Internal temporal<br>Cultural | International supply chain integration (Sheu et al., 2003); international environment (Phatak, 1989) |
| Level-5: socio-organizational integration | External horizontal<br>External vertical<br>External temporal<br>Shared-vision | Interface integration (Truman, 2000); Total Information Solution or External Information Management (Li, 1999); EDI (Cash, Eccles, Nohria, & Nolan, 1994; Choudhury, 1997; Emmelhainz, 1993; Hart & Estrin, 1991; Iacovou, Benbasat, & Dexter, 1995; Nygaard-Andersen & Bjorn-Andersen, 1994; Ramamurthy, Premkumar, & Crum, 1999); internet (Scheer & Habermann, 2000) |
| Level-4: organization integration | Internal vertical<br>Internal horizontal<br>Internal temporal<br>Strategic | Functional integration (Al-Mashari & Zairi, 2000; Burbidge et al., 1987; Hammer & Stanton, 1999; Yates & Benjamin, 1991); electronic exchange environments (Truman, 2000); and Level-4 integration (Meredith & Hill, 1990); and interrelatedness (Rotemberg & Saloner, 1991) |
| Level-3: islands of technology integration | Horizontal<br>Vertical | Internal integration (Truman, 2000); Level-2 integration (Meredith & Hill, 1990); functional integration (Burbidge et al., 1987); horizontal integration (Bullers & Reid, 1990); data integration (Bhatt, 2000); enterprise integration (Hasselbring, 2000; Mendoza et al., 2006; Rotemberg & Saloner, 1991); system integration (Rockart, 1989) |
| Level-2: system–user integration | Ergonomic<br>Cognitive<br>Human–computer interaction | Compatibility integration (Rotemberg & Saloner, 1991); technology adoption (Hwang, 2005) |
| Level-1: system-specification integration | Specification<br>Compatibility | Middleware integration by Hasselbring (2000); Level-1 integration by Meredith and Hill (1990); and internal integration by Truman (2000) |

integration where he argues that Level-2 integration is accomplished by building on Level-1 and his model could be applied to manufacturing and non-manufacturing alike. Building on the strengths of this model, we expanded it to include other types of integration mentioned in the literature. This resulted in a six-level ERP integration model (Fig. 1) (Grant & Tu, 2005). It is a stage-growth maturity model for achieving integration using ERP (Holland & Light, 2001). The model represents the external environment as a rectangle and the company as a circle. The company is comprised of six interrelated levels of integration connected to the environment via inputs and outputs represented by the heavy arrows. Smaller arrows represent connection between various levels of integration.

The types of integration that comprise each of the six levels are listed in Table 2. The left column of the table represents the six levels of integration while column two represents various types of integration that make up each of the six levels. Column two helped us to frame our survey questions. For example, Level-5 deals with SCM, which could be an example of external horizontal integration; hence one of the survey questions, construct 5-1, asks respondents if they use their ERP to contact suppliers. Column three identifies various studies that support the types of integration listed in column two. The six interrelated levels of integration represent separate dimensions of ERP integration discussed in the upcoming sections.

### 3.1. Level-1: system-specification integration

System-specification is the lowest level of integration and is concerned with specification integration and compatibility integration. Specification integration focuses on the system's technical design specifications at the software, hardware, and application level of stand-alone equipment. It requires the computer hardware to support the specifications of the ERP application which should be compatible with the operating system. Compatibility integration addresses the level of compatibility between the various system components. It should also concern itself with the efficient use of human resources (Rotemberg & Saloner, 1991). Since this is the lowest level of integration, we believe it should be widespread because it is the foundation for higher levels of integration.

### 3.2. Level-2: system–user integration

System–user integration is concerned with ensuring that users are integrated with the technology and the environment. It involves two types of integration: ergonomic integration and cognitive integration. Ergonomic integration ensures that the system and the environment are ergonomically designed. This means that users' graphical user interface, keyboard, software, and hardware are user-friendly. Cognitive integration ensures that the communication (i.e., error messages, information, etc.) between system and user is intelligible, useful, and consistent with the user's frame of reference. Integration between the user, the technology, and the environment cannot be achieved if the user suffers cognitive dissonance based on human–computer interaction (Hwang, 2005; Kim, 2012; Ozok & Wei, 2010) and ergonomic literature (Pourshahid, Amyot, Peyton, Ghanavati, & Chen, 2009; Rotemberg & Saloner, 1991).

### 3.3. Level-3: islands of technology integration

Islands of technology integration links geographically dispersed islands of technology throughout the firm. Integration at this level concerns the ability of these islands to communicate with each other. This type of integration is the result of ad-hoc development that lacked enterprise-wide integration (Mathew, 2006; Themistocleus et al., 2002), and so ERP is often the solution to this problem (Truman, 2000). It involves horizontal integration and vertical integration, both of which are necessary for sharing information between the islands. Horizontal integration is the passing of data between islands to facilitate coordination, collaboration, decision-making, and task performance. Vertical integration is required for the passing of data for management control.

### 3.4. Level-4: organization integration

Organization integration is the ability to support the business goals and objectives across the entire company. It is concerned with value chain integration that manages the efforts of various functions across the value chain (Rockart & Sbort, 1989; Sheu et al., 2003) and involves four types of integration: (1) internal vertical integration, (2) internal horizontal integration, (3) strategic integration, and (4) internal temporal integration. Internal vertical integration is the passing of information from strategic management to non management and vice versa. Strategic integration measures how well the information systems support the organization's strategic goals, objectives, and critical success factors (CSFs). Internal temporal integration measures the effectiveness and coordination that exists between groups, functions, departments, and individuals. Level-4 integration requires business process reengineering (Bhatt, 2000), a difficult and disruptive technology (Davenport, 1998; Kumar et al., 2000; Markus & Tanis, 2000).

### 3.5. Level-5: socio-organizational integration

Level-5 integration involves linking the company to customers, suppliers, strategic partners, government, and civic institutions. It integrates customer relationship management, supply chain management (SCM) (Mendoza, Perez, & Griman, 2006; Scheer & Habermann, 2000; Sheu et al., 2003; Zheng, Yen, & Tarn, 2000), and coordinates the task environment (Truman, 2000). It involves four types of integration: (1) external horizontal, (2) external vertical, (3) external temporal and (4) shared-vision integration. External horizontal integration measures primarily the linkage with customers, suppliers and other industry partners. External vertical integration measures how well companies are integrated with external control agencies such as city, state, and federal institutions. External temporal integration is measured by how well companies coordinate their activities with external institutions on a timely basis. Shared-vision integration is the sharing of a common vision between business partners.

### 3.6. Level-6: global integration

Companies must operate as a single global entity rather than independent geographic entities (Ein-Dor & Segev, 1993; Fiderio, 1990) and must be viewed as international with a domestic component. Level-6 integration is concerned with integration across national and cultural boundaries, the highest level of integration (Rochester & Douglass, 1992). It deals with issues of language, time, culture, politics, customs, and management style (Hofstede, 1983; Simchi-Levi, Kaminsky, & Simchi-Levi, 2000; Trompenaars & Hampden_turner, 1998), as well as the demands of the global economy (Barker, 1993; McGowan, 1989). Level-6 integration consists of three types of integration: (1) international horizontal integration, (2) international temporal integration, and (3) cultural integration. International horizontal integration is concerned with the effectiveness of doing business across national borders and refers to all data and information that cross them. International temporal integration is related to companies doing business in several countries with different time zones. Cultural integration forces companies to recognize the differences and nuances of other cultures. Different cultures pose unique linguistic, cultural, legal, economic, and political problems.

#### 3.6.1. Stages of growth

A brief review of the stages of growth model is warranted because it provides the underpinnings for the six-level integration model proposed in the paper. The assumption of the proposed model is that each integration level builds upon lower levels. Each level has a set of variables and issues that are somewhat unique. These assumptions are consistent with the stages of growth model first proposed by Gibson and Nolan (1974). It consists of four distinct stages of EDP growth, where each stage builds upon the other (see Fig. 2). The four stages are initiation, expansion, formalization, and maturity, each with its own distinctive set of issues and problems. Stage I is where technology is first introduced; stumbling occurs and early successes lead to increased interest and

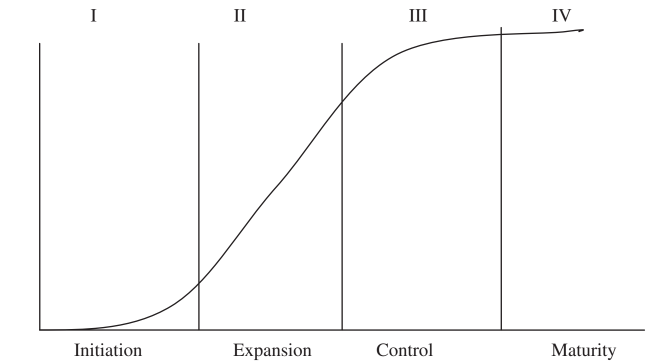


**Fig. 2.** Stages of IS growth (Gibson et al., 1974).

experimentation. Stage II is where rapid interest in the technology occurs, leading to more experimentation and uncontrolled growth. Stage III is where the proliferation of the technology is controlled and managed. At Stage IV the technology is well understood and considered mature. In 1979 the model was revised to include six stages and then later expanded to nine (Norlan, 1979). The growth model has been widely applied to topics including e-commerce (Chen & McQueen, 2008), IT outsourcing (Solli-Saether & Gottschalk, 2008), organizational strategy (Kooros and Aslani, 2005), e-business (Jones & Muir, 2006), marketing (Chen, Blankson, Wu, & Chen, 2005), data warehousing (Watson, Ariyachandra, and Matyska, 2001), knowledge management (Gottschalk, 2002; Gottschalk & Khandelwal, 2004), organizational growth (Kazanjian & Drazin, 1989), and IS Planning (King & Teo, 1997). The concept of stages of growth is similar to the journey required to implement levels of integration as companies start with low levels of integration and work their way to higher levels as they mature. Companies achieve integration by working their way up the integration ladder and this growth is exhibited through varying degrees of integration among companies. This variation is indicative of integration growth often dictated by company maturity and business strategy. The decision to operate regionally, nationally, or globally directly influences the level of integration that is pursued. Companies that operate regionally would seldom pursue global and in some cases socio-organizational integration. These two types of integration were not possible in the absence of e-commerce, the internet, EDI, and SCM technologies. Companies with high levels of integration (levels-5 and 6) took years to achieve that success by building on the growth and success of lower levels. Higher levels of integration can only be achieved by embarking on a journey of integration growth, building one level at a time. Global integration cannot be achieved by skipping lower levels.

## 4. Research method

We conducted an online survey of one hundred and twenty two ERP professionals. The survey participants voluntarily participated in the survey and were asked to complete it based on their perception of the six levels of ERP integration that exist in their company. The six levels of ERP integration are system-specification integration (Level-1), system–user integration (Level-2), island-of-technology integration (Level-3), organizational integration (Level-4), socio-organizational integration (Level-5), and global integration (Level-6). We developed the items for each construct based on the definition of each construct. We made every attempt to develop the survey items based on the convergent and discriminant validities. We endeavored to achieve high face validity and reliability by using simple and easy to understand wording. In the pilot test with the graduate students in the business school, we reworded and removed some items and collected the valid items.

Following standard measure development procedures (e.g., Churchill, 1979; Davis, 1989; Straub, 1989; Yi & Davis, 2003), each scale was developed through iterative steps including specifying the domain of the constructs, generating a sample of items, pilot-testing and purifying the items, collecting additional data, and assessing the reliability and validity of the measure. Throughout the scale development processes, considerable efforts were made to ensure the content validity of the study variables and to make distinctions among the different dimensions of ERP integration. Using the final set of items from the pilot test, the main study was conducted in a field setting.

In the main test conducted by the online survey, one hundred twenty two ERP professionals volunteered to participate in the study. Chin (1998, p. 311) advises that "if one were to use a regression heuristic of 10 cases per indicator," the sample size requirement would be 10 times (1) the largest number of formative indicators or (2) the largest number of independent variables impacting a dependent variable, whichever is the greater. Our model has six formative indicators, thus a sample size of 122 is more than double of the minimum required sample numbers. Therefore, our sample size is more than adequate for the PLS estimation procedures.

The survey attracted a wide array of IT professionals including business analysts, ERP consultants, network engineers, project managers, and software developers. Eighty seven percent of the ERP systems were internally developed, and the average ERP experience was 4.27 years. Sixty eight percent of ERP projects in our study were completed and seventy percent of the companies have more than one thousand employees. The survey participants came from thirty six industry sectors including technology, healthcare, finance, consulting, and education. Appendix 1 shows the detailed items and loadings used in the main test. All questionnaire items used a 5-point Likert-type scale where 1 = completely disagree, 3 = neither agree nor disagree, and 5 = completely agree. We saw no difference between the earlier and later participants of the survey based on an ANOVA test, showing that non-response bias was not an issue.

To assess the common method bias problems in the survey design, we first ran Harman's one-factor test (Podsakoff & Organ, 1986). In this test, all the principal constructs were entered into a principal components factor analysis. Evidence of common method bias exists when a single factor emerges from the analysis, or one general factor accounts for the majority of the covariance in the independent and dependent variables. Since each of the principal constructs explains roughly equal variance (six principal constructs from 5.3% to 11.1%), the test results do not indicate substantial common method bias.

## 5. Empirical test results

Measure validation and model testing were conducted using PLS Graph Version 3.0 (Chin & Frye, 1998), a structural equation-modeling (SEM) tool that utilizes a component-based approach to estimation. PLS makes few assumptions about measurement scales, sample size, and distributional assumptions (Chin, 1998; Falk & Miller, 1992; Fornell & Bookstein, 1982; Wold, 1982). Compared with covariance-based SEM tools such as LISREL and EQS, PLS is more appropriate for exploratory research of new phenomena, which is the case in our study (Chin, 1998).

We evaluated the psychometric properties of the study variables through confirmatory factor analysis using a measurement model in which the first-order latent variables were specified as correlated variables with no causal paths. The measurement model was assessed by using PLS to examine internal consistency reliability and convergent and discriminant validity (Barclay, Higgins, & Thompson, 1995; Chin, 1998; Yi et al., 2003; Gerdes, Stringam, & Brookshire, 2008). Internal consistencies of 0.7 or higher are considered adequate (Barclay et al., 1995; Chin, 1998; Yi et al., 2003). To assess convergent and discriminant validity, the square root of the average variance extracted (AVE) by a construct should be at least 0.707 (i.e., AVE > 0.50) and should exceed that construct's correlation with other constructs. Table 3 shows internal consistency reliabilities, convergent and discriminant validities, and correlations among latent constructs. All six internal consistency reliabilities exceeded the minimal reliability criteria (0.7). Also, satisfying convergent and discriminant validity criteria, the square root of the AVE was greater than 0.707 and greater than the correlation between that and other constructs. Collectively, the psychometric properties of the study variables were considered relevant and sufficiently strong to support valid testing of the proposed structural model.

Table 4 presents the factor structure matrix of the study variables. We followed the process to test the factor structure using SPSS and PLS (since PLS does not perform all these calculations) as suggested by Yi and Davis (2003). Specifically, from the output of the PLS measurement model run, the rescaled data matrix and the matrix of latent variable scores (the eta matrix) were read by Excel and edited to reorganize the data. Pearson correlations were computed between the seven factor scores and rescaled item scores in this matrix using SPSS to obtain the factor structure matrix of loadings and cross-loadings.

The factor structure matrix showed that all items exhibited high loadings (>.65) on their respective constructs, and no items loaded higher on constructs they were not intended to measure, demonstrating strong convergent and discriminate validity. There are a few relatively high (>0.4) cross-loadings, but that's typical of most exploratory studies. These can certainly be used as clues for future revisions of the instrument. Overall, the six factor solution holds well. Collectively, the psychometric properties of the study variables were considered relevant and sufficiently strong to support the proposed six levels of integration. The PLS structural model and hypotheses were assessed by examining path coefficients and their significance levels. Following Chin (1998), bootstrapping (with 500 resamples) was performed on the model to obtain estimates of standard errors for testing the statistical significance of path coefficients using *t*-test. The six levels of ERP integration were modeled as formative factors. As shown in Table 3, all of six

**Table 3**
Internal consistencies and correlations of constructs ($n = 122$) $p<.001$.

| Construct | AVG | S.D. | ICR | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 |
|---|---|---|---|---|---|---|---|---|---|
| Level 1 | 3.32 | 1.05 | **.84** | **.71** | | | | | |
| Level 2 | 3.32 | 1.09 | **.83** | .43 | **.75** | | | | |
| Level 3 | 3.45 | 1.05 | **.85** | .49 | .34 | **.77** | | | |
| Level 4 | 3.48 | 1.03 | **.91** | .52 | .37 | .58 | **.71** | | |
| Level 5 | 3.27 | 1.10 | **.91** | .20 | .16 | .02 | .23 | **.75** | |
| Level 6 | 3.29 | 1.00 | **.89** | .28 | −.07 | .12 | .09 | .39 | **.74** |

*Note:* All the constructs are on a scale of 1 (negative) to 5 (positive): system-specification integration (Level-1), system–user integration (Level-2), island of technology integration (Level-3), organizational integration (Level-4), socio-organizational integration (Level-5), global integration (Level-6), Internal Consistency Reliability (ICR).

**Table 4**
Factor structure matrix of loadings and cross-loadings ($n = 122$) $p<.001$.

| | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 |
|---|---|---|---|---|---|---|
| Level 1-1 | ***0.70***$^{***}$ | 0.35 | 0.33 | 0.40 | 0.04 | 0.26 |
| Level 1-2 | ***0.78***$^{***}$ | 0.45 | 0.34 | 0.23 | 0.11 | 0.27 |
| Level 1-3 | ***0.64***$^{***}$ | 0.37 | 0.36 | 0.40 | 0.08 | 0.08 |
| Level 1-4 | ***0.77***$^{***}$ | 0.43 | 0.46 | 0.51 | 0.25 | 0.28 |
| Level 2-1 | 0.34 | ***0.75***$^{***}$ | 0.11 | 0.11 | 0.30 | 0.36 |
| Level 2-2 | 0.42 | ***0.78***$^{***}$ | 0.04 | 0.09 | 0.26 | 0.17 |
| Level 2-3 | 0.37 | ***0.77***$^{***}$ | 0.18 | 0.22 | 0.37 | 0.26 |
| Level 3-1 | 0.45 | 0.15 | ***0.79***$^{***}$ | 0.42 | 0.03 | 0.17 |
| Level 3-2 | 0.46 | 0.22 | ***0.91***$^{***}$ | 0.45 | 0.01 | 0.17 |
| Level 3-3 | 0.22 | 0.04 | ***0.66***$^{***}$ | 0.48 | 0.02 | −0.05 |
| Level 3-4 | 0.23 | 0.17 | ***0.70***$^{***}$ | 0.43 | 0.01 | −0.01 |
| Level 4-1 | 0.36 | 0.07 | 0.46 | ***0.66***$^{***}$ | 0.18 | 0.18 |
| Level 4-2 | 0.44 | 0.20 | 0.45 | ***0.73***$^{***}$ | 0.09 | 0.06 |
| Level 4-3 | 0.35 | 0.13 | 0.45 | ***0.73***$^{***}$ | 0.23 | −0.01 |
| Level 4-4 | 0.41 | 0.12 | 0.37 | ***0.66***$^{***}$ | 0.22 | 0.07 |
| Level 4-5 | 0.37 | 0.23 | 0.34 | ***0.71***$^{***}$ | 0.12 | 0.01 |
| Level 4-6 | 0.33 | 0.09 | 0.41 | ***0.66***$^{***}$ | 0.09 | −0.03 |
| Level 4-7 | 0.49 | 0.38 | 0.50 | ***0.84***$^{***}$ | 0.21 | 0.10 |
| Level 4-8 | 0.23 | 0.18 | 0.38 | ***0.69***$^{***}$ | 0.20 | 0.15 |
| Level 4-9 | 0.28 | 0.16 | 0.54 | ***0.71***$^{***}$ | 0.22 | 0.21 |
| Level 5-1 | 0.21 | 0.31 | 0.08 | 0.18 | ***0.75***$^{***}$ | 0.23 |
| Level 5-2 | 0.18 | 0.31 | 0.07 | 0.31 | ***0.75***$^{***}$ | 0.32 |
| Level 5-3 | 0.13 | 0.20 | −0.05 | 0.11 | ***0.74***$^{***}$ | 0.30 |
| Level 5-4 | 0.37 | 0.34 | 0.11 | 0.29 | ***0.70***$^{***}$ | 0.38 |
| Level 5-5 | 0.03 | 0.25 | 0.01 | 0.14 | ***0.81***$^{***}$ | 0.25 |
| Level 5-6 | 0.05 | 0.30 | −0.02 | 0.08 | ***0.81***$^{***}$ | 0.25 |
| Level 5-7 | 0.08 | 0.32 | −0.09 | 0.11 | ***0.80***$^{***}$ | 0.36 |
| Level 6-1 | 0.19 | 0.24 | 0.09 | 0.12 | 0.35 | ***0.79***$^{***}$ |
| Level 6-2 | 0.28 | 0.36 | 0.13 | 0.07 | 0.40 | ***0.82***$^{***}$ |
| Level 6-3 | 0.14 | 0.14 | −0.01 | 0.03 | 0.26 | ***0.69***$^{***}$ |
| Level 6-4 | 0.13 | 0.19 | 0.04 | −0.01 | 0.31 | ***0.77***$^{***}$ |
| Level 6-5 | 0.25 | 0.21 | 0.16 | 0.04 | 0.25 | ***0.72***$^{***}$ |
| Level 6-6 | 0.15 | 0.26 | 0.11 | 0.04 | 0.21 | ***0.69***$^{***}$ |
| Level 6-7 | 0.23 | 0.25 | 0.07 | 0.12 | 0.18 | ***0.65***$^{***}$ |

$^{***}$ $p < .001$.

formative paths of ERP integration were supported within the 0.05 significance level. Variance Inflation Factor (VIF) index (Hwang & Kim, 2007) indicates that multicollinearity is not a problem when it is less than 10. VIF of sub-dimensions were below 10, which showed that multicollinearity was not the problem in this model.

## 6. Conclusion and implications

This study empirically confirmed the existence of the six levels of enterprise integration. The measurement instrument we developed, though subject to further revision, may be used as a tool to identify the current level of ERP integration in a company. More specifically, we conducted a literature review of integration and the role of ERP in enabling enterprise integration. To overcome limitations of existing models of integration, we developed our own. Our proposed model possesses strengths that the prior models did not have because of our deliberate attempt to minimize weaknesses exhibited by those models. The other models are conceptual in nature and so they lack evidence to support the levels of integration they espouse. A major strength of our ERP integration model is the empirical evidence that supports the existence of the six levels of integration espoused by the model.

The proposed model was then used to investigate levels of integration. Our investigation found that there are six different levels of enterprise integration based on the PLS analysis of one hundred twenty two ERP professionals (see Figs. 3 and 4). The investigation of path significance by formative factor analysis provides empirical evidence that six levels of integration exist. The six levels are system-specification, system–user, islands-of-technology, organizational, socio-organizational, and global integration. Each level represents a unique dimension of ERP integration as suggested by the literature and theory. Specifically, global integration is a separate dimension of ERP integration based on the empirical test, suggesting that global ERP implementation characteristics should be investigated as important factors of ERP success. ERP complements other business strategies such as product differentiation (Lawrence & Lorsch, 1967) and cost leadership. While it increases performance, piecemeal implementation leads to isolated islands of ERP technology (Bhatt, 2000); therefore, an enterprise-wide roll out of ERP is recommended (Markus & Tanis, 2000, 2000b).

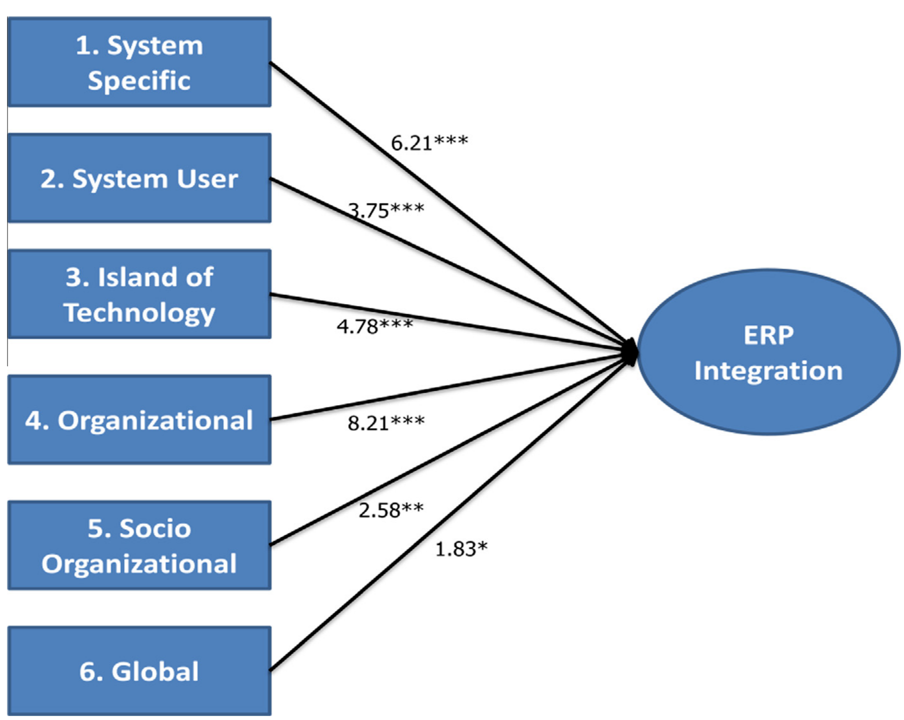


**Fig. 3.** Test results ($n = 122$). *Note*: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

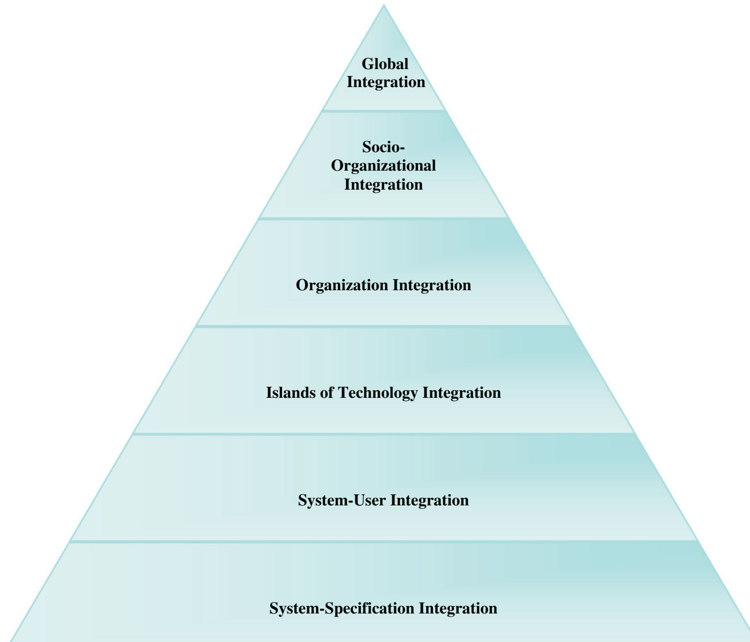


**Fig. 4.** The six levels of enterprise integration.

Companies have to make decisions about which level of integration is appropriate for their business model.

The study has implications for research. It is not surprising that systems-specification integration was supported since we had presumed higher levels of integration build upon lower levels and that integration starts at the lowest level. The existence of socio-organizational integration is explained by the emphasis on CRM and SCM as enablers of integration. They are used to integrate customers and suppliers with internal organizational processes for improved operational and strategic performance. The groundwork is laid for investigating the role ERP plays in achieving levels of integration, which could serve to better explain the connections between various levels. It should help to shed light on implementation challenges and key success factors for various levels of integration. Lastly, this study is useful for investigating appropriate levels of enterprise integration expenditures (Meredith & Hill, 1990).

The integration models discussed in Table 1 include manufacturing and non-manufacturing companies which covers the entire spectrum of industries. The roots of integration can be traced to manufacturing (Mathew, 1986) before spreading to non-manufacturing industries. This evolution is corroborated by various definitions on integration and case studies on integration. Some definitions have a manufacturing slant (Mathew, 1986) while others have a non-manufacturing bias (Bullers et al., 1990; Burbidge et al., 1987). The IS literature is rich with implementation examples of integration (Foster & Regan, 2001; Markus & Tanis, 2000; McAfee, 2003; Nolan, 2001; Truman, 2000). Our integration model is not industry specific and so it could be applied to any type of industry because the six levels of integration span all industries. This claim is supported because the survey instrument was completed by more than one hundred twenty two users from thirty six industries. We made no attempt to target users from any specific industry because we believed integration is pervasive across many industries and the research results back this up.

Companies have to decide which level of integration is appropriate. This decision should be made within the broader context of the company business strategy. Companies that operate regionally and nationally may choose to forego global integration because it would be incongruent with a local businesses strategy. For companies with a global business strategy, global integration is appropriate. Companies that want to maximize their supply chain management and/or improve their customer relationship management should pursue socio-organizational integration. Organizational integration is appropriate for companies seeking to achieve seamless integration across business functions or units. Companies looking to integrate islands-of-technology should pursue islands of technology integration while those seeking to seamlessly integrate users with the business process and the information systems should pursue user integration. Companies do not have a choice when it comes to specification integration because this level of integration is the foundation for any future integration plan.

The study also has implications for practice. There are claims that ERP enhances a company's performance but piecemeal implementation leads to isolated islands of ERP technology, so companies should avoid piecemeal ERP implementation. Global integration is not always the ultimate objective for companies whose business model is to operate autonomously. Hence, global integration is not appropriate for every company, so decisions about the appropriate level of integration will have to be made. Having a more refined view of integration should help companies better focus their integration effort and implementation strategy. Companies should benefit from understanding how to better manage and implement levels of integration.

This study has limitations. First, we did not link the six different levels of ERP integration with the technology acceptance model or IS success models (e.g., Anderson, Al-Gahtani, & Hubona, 2011; Carter, Thatcher, Chudoba, & Marett, 2012). Future research may test these relationships in light of the findings from our study. Second, some construct items may have been a bit unclear and confusing so we used a pilot survey to help with rewording survey questions and the reliability and validity results are supported. Third, we did not ask for additional details about the ERP systems in the survey due to the length of the questionnaire; long questionnaires often lead to poor response rate. Future research may consider more information about ERP systems to better understand the model. Finally, although we were able to empirically confirm the existence of six levels of ERP integration, we were unable to empirically validate that they grow in stages. This is due to limitations of cross-sectional data.

It is our intention to collect longitudinal data in the future to establish relationships between the levels.

## Appendix A. Items for the construct

| Construct | Items |
|---|---|
| Level 1-1 | Our ERP system meets all technical specifications as proposed by the vendor |
| Level 1-2 | Our ERP system hardware meets all software requirements |
| Level 1-3 | All the technical components of our ERP system are compatible with each other |
| Level 1-4 | I'm satisfied with our ERP system in meeting technical specification and compatibility requirements |
| Level 2-1 | Our ERP system was ergonomically designed |
| Level 2-2 | Our ERP system was designed with user interests in mind |
| Level 2-3 | The user interface of our ERP system has not been a cause for complaints |
| Level 3-1 | The functional areas of my company are electronically connected through the ERP system |
| Level 3-2 | Our ERP system has been a major facilitator of data sharing among departments |
| Level 3-3 | Our ERP system links the various data centers of the company together |
| Level 3-4 | Sharing of data among departments is easier with the ERP system |
| Level 4-1 | The ERP system improved our ability to analyze and disseminate information for better decision making |
| Level 4-2 | The use of our ERP system supports our business objectives |
| Level 4-3 | The ERP system offers a clear competitive advantage to our company |
| Level 4-4 | The use of the ERP system facilitates a shared vision among different divisions of our company |
| Level 4-5 | The ERP system makes it easy for departments to exchange ideas |
| Level 4-6 | The ERP system improves the quality of information among departments in our company |
| Level 4-7 | The ERP system improves the timeliness of information sharing among departments in our company |
| Level 4-8 | The ERP system facilitates collaboration among departments |
| Level 4-9 | The ERP system enables business processes in one department to be linked to business processes in other departments |
| Level 5-1 | We use our ERP system to keep in contact with our suppliers |
| Level 5-2 | We use our ERP as the foundation for e-business |
| Level 5-3 | We use our ERP system to communicate with government and regulatory agencies |
| Level 5-4 | Our ERP system makes it easier to coordinate activities with business partners |
| Level 5-5 | Our ERP system helps in defining a shared vision among our business partners |
| Level 5-6 | Our ERP system is useful in supporting common policies and strategies among our business partners |
| Level 5-7 | Our ERP system makes it easy to communicate a common vision among business partners |
| Level 6-1 | Our ERP system has been implemented globally |
| Level 6-2 | Our branch offices around the world use the same ERP system |
| Level 6-3 | Time differences in various parts of the world do not affect the operation of our ERP system |
| Level 6-4 | Differences in languages of other countries do not delay the transfer or processing of information |
| Level 6-5 | Differences in international culture do not pose a problem when processing and transferring data |
| Level 6-6 | Differences in data definitions and database specifications in other countries have not been a problem for us |
| Level 6-7 | Our ERP system conforms to international industry standards required by different countries |

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