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DEVELOPMENT AND VALIDATION OF AN INSTRUMENT TO MEASURE INDIVIDUAL LEVEL ERP ASSIMILATION

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Abstract

Case evidence has shown the important role of individual level assimilation of ERP technology in realizing the business value of implemented ERP systems. However, empirical research in this area has been constrained by the lack of a validated scale for measuring individual level ERP assimilation. This study address this limitation by first theoretically conceptualizing three key dimensions through a multi-case study and then following a rigorous development process to validate a formative measurement instrument for individual level ERP assimilation. The findings show that individual level ERP assimilation consists of width, depth, and innovation, and the proposed measurement instrument is reliable and meets the validity requirements.

Keywords: ERP systems, business value, individual level ERP assimilation, formative measurement instrument.

1 INTRODUCTION

To survive and thrive in the increasingly dynamic and competitive global market environment, Enterprise Resource Planning (ERP) has emerged as one of the most imperative tools to reduce operational cost, enable efficient business processes, and support strategic business decisions (Seddon et al., 2010, Koh et al., 2011). This has resulted in significant investment in ERP systems by firms around the globe (Gao et al., 2014). According to Allied Market Research, the emergence of cloud technology and mobile device could drive the ERP market to reach $41.69 billion by 2020 (Chaudhari and Ghone, 2015). However, like most complex and large enterprise systems, not all ERP projects go according to plans (Sasidharan et al., 2012), and failures are frequent (Liang et al., 2007).

Thus, improving the chances of ERP success has been a special focus of research in the last three decades (Petter et al., 2008, Petter et al., 2013). ERP assimilation has been identified as one of the most significant factors (Liang et al., 2007, Chang et al., 2009, Liu et al., 2011, Saraf et al., 2013). This is primarily because organizations need to balance ERP system-required integration against incumbent business processes. Only after ERP systems are extensively assimilated into operational processes and become institutionalized, firm can achieve the designed operational efficiencies and realize the expected returns on the ERP investment (Liang et al., 2007, Liu et al., 2011). For this reason, there is a rich body of literature on ERP assimilation at the organizational level. Research indicates that individuals are meaningful to organizational ERP success (Petter et al., 2008, Kositanurit et al., 2006). However, in the ERP assimilation literature, the role of individual ERP users has often been overlooked, and research on individual level ERP assimilation is scant. Liu et al. (2011) contended that users play significant roles in ERP assimilation, because without the active involvement of individual users, ERP technology implemented in business processes would be superficial and functional at best. Liu et al. (2011) defined the concept of individual level ERP assimilation and proposed a hierarchy of individual level ERP assimilation with three categories of users based on the level of assimilation.

However, in the IS literature there is no clear set of criteria for measuring ERP assimilation at individual level. Although Liu et al. (2011) described characteristics of ERP users at different levels in the hierarchy, these descriptive characteristics cannot be readily used to assess the level of ERP assimilation in empirical research. Moreover, clearly evaluating individual level ERP assimilation is not just theoretical in terms of research literature, but also very practical in terms of managing ERP system effectively. Understanding the degree of user ERP assimilation will help managers find problematic parts of their ERP systems, distribute relevant resources to target specific users, and ultimately increase the likelihood of ERP system success in firms.

The primary objective of this study is thus to develop and validate a measurement instrument of individual level ERP assimilation. In order to accomplish this goal, we first conducted a multi-case study of five organizations with 38 interviewees. Based on the findings of our case study, as well as prior studies on individual level ERP assimilation, we constructed a multidimensional measurement scale for individual level ERP assimilation and then validated this instrument using survey data and structural equation modelling (SEM) technique.

2 LITERATURE REVIEW ON ERP ASSIMILATION

ERP assimilation is a multiple level phenomenon and occurs at the organizational and individual levels simultaneously (Liu et al., 2011). Table 1 summarizes various definitions. In the following sections, we review relevant studies at the two levels, which serves as a theoretical foundation for this study. Table 2 shows selected studies related to ERP assimilation. To assess ERP assimilation at organizational level, Liang et al. (2007) constructed a three-item formative scale that includes volume, diversity, and depth, as described in Table 3. This three-item scale has been broadly used to explore the antecedents and consequences of ERP assimilation empirically at the organizational level (Wang, 2008, Min et al., 2011, Liu et al., 2013, Saraf et al., 2013, Xu et al., 2015).

Construct	Study	Definition
Organizational level ERP assimilation	Liang et al. (2007)	The extent to which the use of technology diffuses across the organizational projects or work processes and becomes routinized in the activities of those projects and processes.
	Liu et al. (2011)	The extent to which the ERP technology is used in facilitating business processes and the degree it supports business decision making at operational and strategic levels.
Individual level ERP assimilation	Liu et al. (2011)	The degree of cognitive understanding of ERP technology and the extent to which the technology is used beyond routine tasks by an individual user.

Table 1. Definitions that define the concept of ERP assimilation

However, compared with the empirical literature of organizational level ERP assimilation, research on individual level ERP assimilation is glaringly insufficient. Liu et al. (2011) conducted a multi-case study and identified that ERP users can be grouped into transactional users, power users, and VIP users in a pyramid structure of the hierarchical model. Gao et al. (2014), considering social interactions between ERP users, used social network theory as the theoretical lens, and identified that instrumental and expressive ties, external ties, homophily, and centrality facilitate individual level ERP assimilation in a multi-case study.

Study	Year	IS	Level of Analysis		Type			Dimensionality	Indicators	
			IND	ORGA	THEO	EMP	CA	MU-S	FOR	REF
Liang et al. (2007)	2007	ERP		✓		✓		✓	✓	
Wang (2008)	2008	ERP		✓		✓		✓	✓	
Chang et al. (2009)	2009	ERP		✓	✓					✓
Kouki et al. (2009)	2009	ERP		✓			✓			
Min et al. (2011)	2011	ERP		✓		✓		✓	✓	
Liu et al. (2011)	2011	ERP	✓	✓			✓			
Liu et al. (2013)	2013	IT		✓		✓		✓	✓	
Saraf et al. (2013)	2013	ERP		✓		✓		✓	✓	
Gao et al. (2014)	2014	ERP	✓				✓			
Xu et al. (2015)	2015	ERP		✓		✓		✓	✓	
This study		ERP	✓			✓	✓	✓	✓	
Note: IS=Information System; IND=Individual Level; ORGA=Organizational Level; THEO=Theoretical/Conceptual; EMP=Empirical; CA=Case Study; MU-S=Multiple Sub-Dimensional; FOR=Formative; REF=Reflective										

Table 2. Summary of ERP assimilation literature

Study	Sub-dimensions and Items
Liu et al. (2013), Liang et al. (2007), Min et al. (2011), Saraf et al. (2013)	Volume: Percentage of the firm's business processes that are using the ERP system (%); Diversity: Number of functional areas that are using the ERP system (%); Depth: For each functional area identified above, identify the level at which the ERP system is used: a. Operation b. Management c. Decision making
Wang (2008), Xu et al. (2015)	Volume: Percentage of the firm's business processes that are using the ERP system (%); Diversity: Number of functional areas that are using the ERP system (%);
Chang et al. (2009)	Our firm is successful in applying information to support the business strategy of being a low-cost producer. Our firm is successful in applying information to execute inbound logistics activities.

Table 3. Measures and items for ERP assimilation at the organizational level

Nevertheless, extant studies on individual level ERP assimilation are primarily case studies and have not empirically validated key constructs and measurements. We argue that a primary reason is the difficulty in measuring individual level ERP assimilation. A reliable and valid measurement scale is critically needed as an analytical and benchmarking tool for researchers and practitioners.

3 METHODOLOGY

Following well-recognized and comprehensive methodologies for instrument development and validation (MacKenzie et al., 2011, Schmiedel et al., 2014), we employed a multi-step approach to develop and test a scale to measure individual level ERP assimilation, as depicted in Figure 1. Given the nascent nature of the research objective, we chose to first conduct a multi-case study to explore the attributes of individual level ERP assimilation. Then we followed the development process to construct and validate the measurement scale. Thus, this study consists of two studies (a case study and an empirical study) as shown in Figure 1.

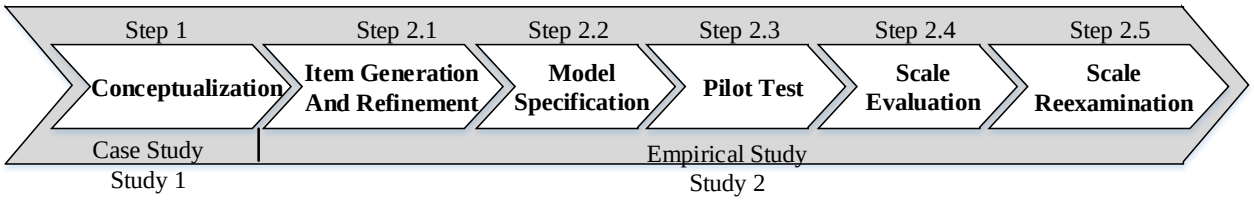

Figure 1. Overview of Scale Development Procedure

4 STUDY 1: DIMENSIONS OF INDIVIDUAL LEVEL ERP ASSIMILATION

A multi-case research methodology is appropriate for this study because of three reasons. Case study is especially useful for developing theoretical insights when little is known about a phenomenon, or research focus on areas that current perspectives seem inadequate and do not address well (Eisenhardt, 1989, Yin, 2014). Second, multiple cases permit a replication logic (Yin, 2014), and are effective to yield more robust and generalizable theory with comparative data (Santos and Eisenhardt, 2009). Finally, interviews with frontline ERP users and IT experts are critical to ensure the content validity through identifying a broad set of dimensions that cover key aspects of individual level ERP assimilation (Straub et al., 2004, Andreev et al., 2009)

4.1 Case Study Design

Following the general guidelines of case studies (Yin, 2014, Paré, 2004), a case study protocol was first developed to outline the scope and objectives of research, the nature of research design, the characteristics of target interviewees, firms, and industries, and the initial set of interview questions. In order to have reasonable degree of generalizability of the findings, we visited companies that had successfully implemented ERP systems from distinct vendors and in different industries. Moreover, to triangulate the case evidence, informants with diverse organizational roles and background (including top managers, middle managers, and employees) were recruited to enrich the viewpoints related to and increase the validity of insights about the dimensions of individual level ERP assimilation.

Firm	Type	Location	Industry	Annual revenue (million RMB)	Number of employees	ERP vendor	Used years	ERP modules in use
A	Joint venture	Harbin	Aviation	300	231	SAP	10	FI, CO, QM, MM
B	State-owned	Daqing	Petroleum	66,700	5000	SAP	4	FI, CO, MM, PS, PM
C	State-owned	Weihai	Pump	1,000	1300	DigiwinSoft	12	SA, PU, IN, PR, FI, PDM
D	State-owned	Weihai	Tire	14,000	9900	Oracle	15	SA, PU, IN, PR, FI, CRM, SRM
E	Private	Weihai	Carpet	1,000	2000	Developed in house	10	SA, PU, IN, PR, FI
Note: FI=Finance; CO=Controlling; QM=Quality Management; MM=Materials Management; PS=Project System; PM= Plant Maintenance; SA=Sales; PU=Purchasing; IN=Inventory; PR=Production								

Table 4. Profiles of case firms

Based on these criteria, we initially contacted 9 firms, and 5 were eventually selected primarily according to their willingness to cooperate. All these firms had implemented ERP systems that include finance, inventory, sales and other major modules. Table 4 lists the profiles of the participating firms and we use A, B, C, D, and E to protect their identities.

4.2 Data Collection and Analysis

Firm	Description of Informants and Code		Total	Interview time (min)	Transcript (words)
A	Middle manager	IT manager (A_{13})	13	353	88,400
	Employee	QM module (A_1 , A_3), MM module (A_2 , A_5 , A_{10} , A_{11}), FI module (A_6, A_7), CO module (A_8, A_9), IT department (A_4, A_{12})			
B	Middle manager	IT manager (B_{10})	10	340	77,000
	Employee	FI/CO module (B_1, B_2, B_3), MM module (B_4, B_5), PM module (B_6), PS module (B_7, B_8), IT department (B_{10})			
C	Top manager	CIO (C_1)	2	223	45,900
	Middle manager	IT manager (C_2)			
D	Top manager	CFO (D_1)	6	261	39,400
	Middle manager	Procurement department (D_2), Finance department (D_4)			
	Employee	Procurement department (D_3), Finance department (D_5, D_6)			
E	Top manager	CIO (E_1), CFO (E_5)	7	365	67,200
	Middle manager	IT manager (E_2), Finished products warehouse (E_3), Materials warehouse (E_4)			
	Employee	Sales department (E_6, E_7)			
Total			38	1542	317,900

Table 5. Profiles of informants

We collected data over three different times because of the different locations of the 5 firms. The first data collection took two days in firm B in December 2013 with 2 interviewers. The second data collection was in firm A in January 2014. The last data collection took three days in October 2014. Each individual informant was interviewed face-to-face, and digitally recorded with the consent of the participant. Table 5 shows the profiles of informants in each firm. A total of 38 individuals were interviewed, including 4 top-level managers, 8 middle-level manager, and 26 employees, resulting in about 26 hours of audio recordings. These recordings were later transcribed into text documents for case analysis.

The text analysis software of NVivo 8.0 was used to encode the transcripts following an open coding strategy. The passages in the transcripts were first coded as free nodes based on the central ideas. Most of the free nodes were grouped into tree nodes if the concepts were similar or related to other nodes in a tree, and finally, four tree nodes emerged. The coding process was conducted based on the criterion "clear and detailed"(MacQueen et al., 1998) and lasted about one month.

4.3 Main Findings

During the post-hoc review of the free nodes, a clear pattern of individual level ERP assimilation emerged. In every company we visited, the descriptions to distinguish "advanced" users from "average" users naturally fall into four categories and we labeled them as routine use, width, depth, and innovation. However, using ERP systems to finish daily work correctly and timely is mandatory and basic requirement for users, so that belongs to routine use and does not count toward individual level ERP assimilation. Individual level ERP assimilation is more than routine use (Liu et al., 2011), and is achieved beyond direct experience with the system in routing use. Therefore, only width, depth, and innovation were identified for inclusion in individual level ERP assimilation. Table 6 summarizes the definitions and characteristics of width, depth, and innovation.

Tree node	**Definitions**	**Characteristics**
✓Width	The breadth of ERP knowledge that users know	✓Get the big picture. ✓Grasp knowledge of other ERP modules. ✓Know more ERP functions. ✓Extend operations. ✓Know the ins and outs of their jobs.
✓Depth	The extent to which users understand ERP technology and the degree to which ERP technology is integrated into business knowledge	✓Know the inner workings of ERP systems. ✓Dive deep into details. ✓Understand ERP deeply. ✓Integrate IT into business processes. ✓Know the internal logic of ERP systems.
✓Innovation	The fact that ERP users utilize ERP systems to accomplish tasks in novel ways	✓Have innovative ideas. ✓Make innovative use of the ERP system. ✓Break normal procedures.

Table 6. Definitions and characteristics of width, depth and innovation

According to the prescription of MacKenzie et al. (2011), two questions are used to determine whether a construct is multi-dimensional: "How distinctive are the essential characteristics form each other?" and "Would eliminating any one of them restrict the domain of the construct in a significant or important way?" (p. 301). Width, depth, and innovation each represents a distinct aspect of individual level ERP assimilation. Therefore, we propose that individual level ERP assimilation is multi-dimensional, and width, depth, and innovation are three essential sub-dimensions. Table 7 shows the three dimensions identified by the informants at different positions in different firms. In the following section, we provide a detail account of the three dimensions with case evidence.

Dimension	**A**		**B**		**C**		**D**			**E**		
	M	**E**	**M**	**E**	**T**	**M**	**T**	**M**	**E**	**T**	**M**	**E**
Width	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Depth	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Innovation	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
Note: T= Top managers; M = Middle-level managers; E= Employees.												

Table 7. Dimensions of individual level ERP assimilation in case firms

4.3.1 Depth

Liu et al. (2010) proposed that firms use ERP systems at different levels, like supporting operations, supporting management decision making, and supporting business strategies. But for individual level ERP assimilation, we found that our informants preferred to divide ERP knowledge into two parts: ERP technology and business knowledge. And two of the most mentioned points used to describe ERP users are whether users know the inner workings of ERP systems and whether users can integrate ERP technology into complicated tasks and practical business needs. Thus, following the definition of depth at the organizational level of Liang et al. (2007), we define these characteristics as depth reflecting the extent to which users understand ERP technology and the degree to which ERP technology is integrated into business knowledge. During the interviews, most of informants expressed that "advanced" users had deeper depth than "average" users. One user of finance department of firm D stated:

"There are some obvious difference among employees. If someone wants to have a thorough understanding of the ERP system, she/he needs to pay more attention to it. It's up to herself/himself. The fundamental operations and knowledge are there and easy to grasp. But the ERP system is very powerful, what we know is just surface functions. We know how, but don't know why. But key users like X, are different. They not only know how, but also know why, know how the ERP system works. This is very important. I can operate correctly and rapidly, but once an error or warning occurs, I can do nothing but ask others for help, because I don't know why it appears, not to mention resolving it. If I know the underlying working principles, I can analyze the reasons and find the solutions." (D_6)

This sentiment is echoed by the CIO of firm C:

"Many users in our company don't know the internal logic of the ERP system. This limits their usage of the ERP system. Take the monthly report as an example. Some users can create the report for me. But if you ask them how these data are calculated, they may tell you that this is what the system provides. They don't know the computational logic behind the report like where these data are stored, which data the report is extracted from, they have no idea about these. Actually, what users need is not only the simple operational steps, but also to be competent to analyze whether these data are correct or reasonable, what problems these data reflect and so on. But in our company there is only a small minority of such users." (C_1)

Another important point mentioned by the informants is the integration of ERP technology and business knowledge. In all 5 firms we visited, most informants stated one common feature of key users is that they have simultaneously mastered IT knowledge and business knowledge well, as suggested by one user of firm A:

"For a routine operation, if there is no error in the system, I just need to follow the order to complete the task step by step. But obviously, it's not enough. For example, if something unusual appears because of cost allocation, I need to figure out how it comes up from a business perspective, and I also need to know how the system is set up in the background. But for users in the production lines, their jobs are simply to input the data. When they need to make a simple report, they just need to click a button, the report would be finished. We are definitely different. If I want do one thing, I must consider how and why."(A_8)

These evidences support our argument that depth is a significant dimension of individual level ERP assimilation.

4.3.2 Width

Width refers to the breadth of ERP knowledge that users know. Width states the fact that some users only grasp the ERP knowledge relevant to their own required functions, while some users also know the ERP knowledge of the other users' functions. This difference is regarded as an important sign to distinguish between "advanced" and "average" users, as expressed by the CIO of firm D:

"*I think that assimilation is only suitable for users who are middle-level employees, at least a team leader or unit director. These users have a big picture in their minds. Although they may not deeply master every function of ERP systems related to their teams or unit, but even knowing a little shallow [but broad] knowledge could influence their thinking profoundly, see things differently, and manage from an entire operational process perspective, even from an organizational point of view. For frontline employees, they tend to think at their own task level. But team leader and unit directors are different. They have much wider visions. Thus in our company, the assimilation of the ERP system depends on these experienced middle-level employees. They could understand the value, significance, and returns of the ERP system from the managerial level instead of the operational level.*"(D_1)

The IT manager of firm E also confirmed that more extensive ERP knowledge is a significant indicator to measure the level of assimilation of ERP users. He stated:

"*In the finance department, there is a representative user. She is the most important and frequently asked user in her department. She has more knowledge and experience than others. This is because that there were several opportunities of job rotation, and she took these chances to learn almost all businesses of the finance department, while others only know ERP knowledge limited to their job responsibilities. No one is more all-rounded than her [in business and ERP knowledge]*. "(E_2)

Users of firm A expressed similar opinions more directly:

"*In my opinion, there are three things that can show one user understands and uses the system better than me. First, does this user learn ERP more broadly than me? Second, does this user have more ERP training than me? And finally, does this user perform more ERP operations than me?*"(A_7)

Our interviews confirmed that width is a key dimension to evaluate the degree of individual level ERP assimilation. This is similar with the diversity concept at organizational level ERP assimilation defined by Liang et al. (2007). While diversity describes the number of functional areas an organization uses the ERP system, width in this study reflects how many ERP functions a user uses.

4.3.3 Innovation

Innovation describes the fact that users utilize ERP systems to accomplish tasks in novel ways which were not originally conceived and deployed during the rollout of ERP systems. During the interviews, we found that many users, through accumulation of experiences, gave useful advices to IT department, and ultimately led to company-wide changes to the ERP systems, as described by the manager of finished products warehouse of firm E:

"*In our company, innovation is a key indicator to evaluate individual annual performance. In the past year, some users provided very useful suggestions. Take a simple example, one storekeeper broke the routine process and proposed a completely new set of coding criteria to mark storage locations in the system. After discussion with the IT staff, they thought it was feasible. After deploying the changes, the storekeepers were able to use the system more conveniently and efficiently. There are many such examples. Through such continuous improvement, we can make the ERP system better.*"(E_3)

One user of firm A described similar simulations:

"*In 2009 we used CO02 (one transaction code of the ERP system) to close the engineering order. But the transaction code had a potential risk: even if the production material data weren't completely inputted, CO02 still could close the order. If the worker didn't recognize it, it's harmful that the incomplete material data were used. So we developed a new transaction code to check. If the material list wasn't complete, the system would display a warning. It's very useful. We have many transaction codes like this. We named such codes with the first letter as 'Z' to represent that they are innovatively created by ourselves.*"(A_5)

These case evidences confirmed that innovation is an essential dimension of individual level ERP assimilation.

4.3.4 Relations between the Sub-dimensions and Individual Level ERP Assimilation

Based on the findings of the case study, we concluded that individual level ERP assimilation is multi-dimensional with at least three key sub-dimensions. The next conceptual question is about the nature of the relationships between the sub-dimensions and the higher-order construct (MacKenzie et al., 2011). Following the prescription of MacKenzie et al. (2011), we propose that the three sub-dimensions are formative indicators of individual level ERP assimilation for three reasons. First, the three sub-dimensions originated from characteristics but not manifestations. Second, width, depth, and innovation together determine a user's level of individual level ERP assimilation. The last and above all, an increase in the level of one of the three sub-dimensions might be associated with an increase in the overall level of ERP assimilation, but without necessarily being associated with changes in the other two sub-dimensions.

Our interviews provided relatively rich evidence to support this conclusion. For example, the manager of finished products warehouse of firm E stated that even if a user only knows operational procedures relevant to his tasks, he still could discover novel ways to use the ERP system. One employee of IT department of firm A argued that width and depth have no necessary relations,

"*Some users can operate different functions of the ERP system, but they just know how to operate. However, some*

users not only know the operations, but also can explain the working principles. Such users are desirable. But there are only a few users who can reach this level."(A_4)

Through a multi-case study, we have completed the first step toward developing a scale for measuring individual level ERP assimilation, which involves defining the conceptual domain of the construct and evaluate the construct dimensionality (MacKenzie et al., 2011). We propose that width, depth, and innovation are the three key dimensions to form individual level ERP assimilation. Next, we attempt to validate this measurement with empirical data.

5 STUDY 2: MEASUREMENT DEVELOPMENT AND VALIDATION

5.1 Step 1: Item Generation and Refinement

After the conceptualization of the construct has been completed, the next step is to produce a set of measurement items that capture the essential aspects of each sub-dimension of the individual level ERP assimilation construct (Diamantopoulos and Siguaw, 2006, MacKenzie et al., 2011). Because of the scant ERP assimilation literature at the individual level, there were no existing measurement instruments as references except for items of organizational level ERP assimilation listed in Table 3. We therefore reviewed the free nodes of the characteristics that were coded from the interview transcripts and composed the three sub-dimensions of individual level ERP assimilation in Table 6. These characteristics served as input for the creation of candidate items. We followed the four principles in creating new items recommended by MacKenzie et al. (2011): the wording of the items is as simple and precise as possible; the items did not contain ambiguous and unfamiliar terms; a complicated syntax is avoided; and obvious social desirability is not permitted.

In order to evaluate the content validity of the created items and ensure that the items reflect the content adequacy of a measuring instrument (Diamantopoulos, 2011, MacKenzie et al., 2011), we adopted two methods. First, the items were created according to the transcripts of interviews of ERP users, which assured that these items reflect the actual applications of ERP and cover key aspects mentioned by interviewees. Second, we discussed the measurement items with ERP experts to determine whether the candidate items fit the matching dimensions (Straub et al., 2004). The experts consisted of both scholars, ERP users, IT managers, and IT staff. We provided the definition of each dimension and the related candidate items, the experts were asked to assess whether the items are helpful in measuring the dimensions, and provide suggestions on how to improve them. After several rounds of deletion, merger, and revision, the initial set measurement items were created.

5.2 Step 2: Model Specification

The next step is to formally specify a measurement model that captures the relationships between the indicators and the individual level ERP assimilation construct (MacKenzie et al., 2011). Considering the relationships between the three sub-dimensions and the individual level ERP assimilation construct, we constructed a reflective-formative hierarchical component model, used the repeated indicator approach (Lohmöller, 2013), and modeled all the manifest indicators of the underlying lower-order latent variables (i.e., width, depth, innovation) as reflective indicators of the higher-order construct (i.e., individual level ERP assimilation), as depicted in Fig.2. The repeated indicator approach works best when all lower-order components have the same number of indicators (Lohmöller, 2013, Ringle et al., 2012), as in our case. Moreover, the indicator reuse approach is suitable for the analysis of a hierarchical component model in partial least squares structural equation model (PLS-SEM) (Lohmöller, 2013, Ringle et al., 2012). Therefore, PLS-SEM is suitable to assess outer and inner models of the hierarchical component model of individual level ERP assimilation in this study, which is the first stage.

Furthermore, if the outer and inner model evaluations suggests reliability and validity, a redundancy analysis should be cross-validated on a fresh set of data to assess the validity of the designated set of formative indicators (Ringle et al., 2012, Chin, 1998), which is the second stage as depicted in Figure 2. The means to perform a redundancy analysis of a reflective-formative hierarchical component model in PLS-SEM is to create two latent constructs: one construct is measured with formative indicators which are the latent variable scores for the lower-order components in the first stage, and that construct is causal to a second, conceptually equivalent construct measured with reflective indicators (Mathieson et al., 2001, Cenfetelli and Bassellier, 2009). Therefore, three global reflective indicators of individual level ERP assimilation were also generated according to the coded interview transcripts.

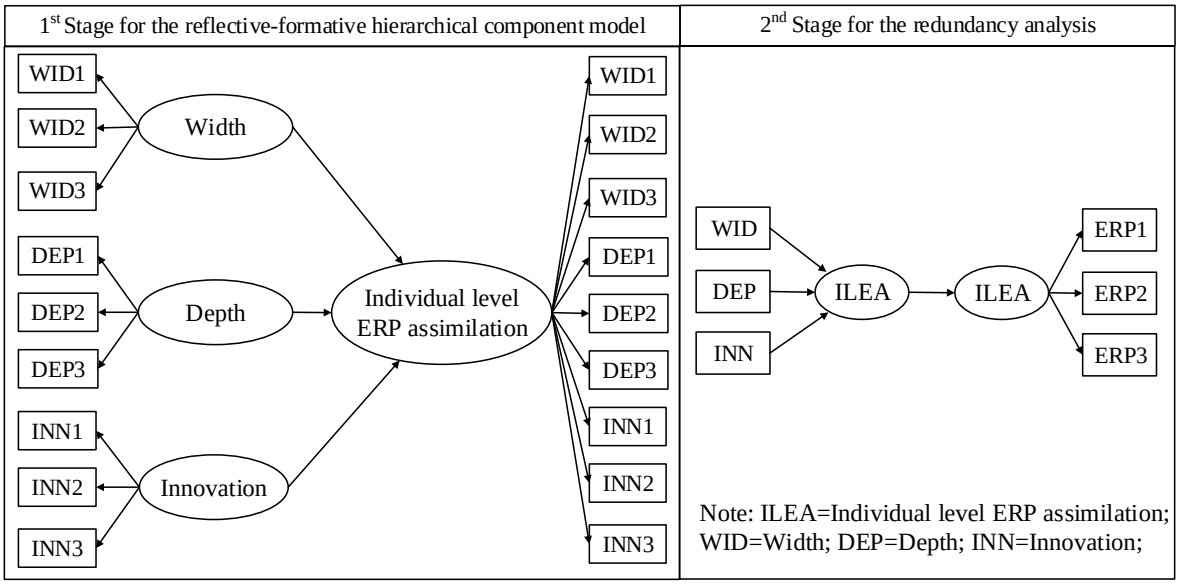

Figure 2. Two-stage approach for the hierarchical component analysis of individual level ERP assimilation

5.3 Step 3: Pilot Test

Once the measurement model was specified, data need to be obtained to test construct validity and reliability (Diamantopoulos and Winklhofer, 2001, Diamantopoulos, 2011). We conducted a pilot test to assess the reliability and validity of the instrument. Measurement items for each construct were based on a 7-point Likert scale. The respondents were 53 users of SAP R/3 in an aircraft manufacturing firm in China. Based on the data, we conducted an exploratory factor analysis and revised the items that did not meet the required thresholds. The final measurement items for each construct are shown in Table 10.

5.4 Step 4: Scale Evaluation

5.4.1 Data Collection

Two factors are traditionally considered for data collection in field surveys. First is whether the sample can represent the population for which the measures are designed. Second is the size of the sample. According to Comrey and Lee (2013) and Cattell (2012), the minimum sample size ranges from 100 to 500, and the minimum ratio of the number of respondents to the number of items ranges from 3:1 to 10:1.

To find the right respondents for this data collection, we contacted Yonyou, an ERP vendor with the largest ERP market share in China, for assistance. A regional manager of Yonyou requested all ERP consultants of his company to randomly distribute questionnaires to their clients. To improve the quality of data, the respondents were told that a $2 gift for every qualified questionnaire would be awarded. The gifts were distributed by the ERP consultants according to the unique codes generated after the respondents submitted the questionnaires online. A 7-point Likert scale was used in questionnaires. Overall, 238 respondents participated in our survey, which met the requirement of sample size. The demographics of the respondents are described in Table 8. These respondents were from various industries in two municipalities and 5 provinces in China, representing a wide range of geographic and demographic diversity. Before performing the analysis of the measurement model, we assessed nonresponse bias using Chi-square testes and t-tests on demographic and survey responses respectively, and found no significant differences.

Age	**%**	**Job title**	**%**	**Education**	**%**	**Gender**	**%**
Under 26 years old	7.14	Top manager	5.46	High school	3.78	Male	31.09
26-35 years old	59.66	Middle manager	11.34	Associate degree	18.91	Female	68.91
36-45 years old	28.15	Team leader	13.87	Bachelor's degree	67.23		
46-55 years old	4.20	Employee	69.33	Master's degree	10.08		
Above 55 years old	0.84						

Table 8. Sample demographic statistics

To examine the validity and reliability of our measurement instrument for individual level ERP assimilation, we chose PLS-SEM technique for three reasons. First, as mentioned above, the repeated indicator approach is suitable

for the hierarchical component analysis in PLS-SEM (Lohmöller, 2013, Becker et al., 2012). Second, a PLS approach is more appropriate because our data are not normally distributed, while covariance-based approaches require a normal distribution (Chin, 1998). Third, a PLS approach is typically used when the investigate phenomenon is new and measurement models need to be developed (Chin, 1998).

We performed the data analysis using WarpPLS, because this tool provides two advantages. Multicollinearity among sub-dimensions is not recommended for higher-order constructs with lower-order sub-dimensions as formative indicators (e.g., our measurement model), and WarpPLS allows for nonlinear relationships between variables (Kock and Lynn, 2012). Moreover, WarpPLS reports model goodness-of-fit statistics that are not available in other PLS tools (Schmiedel et al., 2014, Kock, 2012). We conducted three procedures for scale evaluation of the hierarchical component model: evaluating model goodness-of-fit statistics, assessing outer model, and evaluating inner model (MacKenzie et al., 2011, Hair et al., 2012).

Since all data were self-reported, we addressed the threat of common method bias (Podsakoff et al., 2003), following the approach as recommended in Hu et al. (2012). We added a common method factor measured with all the lower-order constructs' indicators and calculated the path coefficients of each single-indicator construct's two incoming paths from its substantive construct and the method factor (Liang et al., 2007). The results show that the average substantive variance explained by all substantive constructs is 88.1% and the average variance caused by the method factor is a meagre 3.7%. The much lower variance value explained by the method factor indicates that common method bias is not a major concern in our study.

5.4.2 Evaluating Model Goodness-of-Fit Statistics

We used five indices recommended by Kock (2012) to assess the model fit with the data. Table 9 shows that all indices met the requirements, implying a good fit model. It's noteworthy that because the repeated indicators approach is used, all variance of individual level ERP assimilation is explained by width, depth, and innovation. As a consequence, average R2 and average adjusted R2 are approximately 1. The value of average block VIF was 2.603, below the rigorous threshold of 3 (Petter et al., 2007), suggesting that multicollinearity among the three lower-order constructs was not a concern in this study. The GoF index of Tenenhaus et al. (2004) is a global criterion for goodness-of-fit. However, the GoF is not applicable when outer models are formative, or when single indicator constructs are involved (Hair et al., 2012). Our reflective outer models and multiple indicator constructs permit the testing of the GoF and the value of 0.926 suggested a good fit model.

Indices	**Model**	**Criteria**
APC	0.370, P<0.001	P<0.001
ARS	1.000, P<0.001	P<0.001
AARS	1.000, P<0.001	P<0.001
AVIF	2.603	acceptable if <= 5, ideally <= 3.3
GoF	0.926	small >= 0.1, medium >= 0.25, large >= 0.36
Note: APC = Average path coefficient; ARS = Average R-squared; AARS = Average adjusted R-squared; AVIF = Average block VIF; GoF = Tenenhaus GoF		

Table 9. General results of the measurement model

5.4.3 Assessing Outer Model

Outer model evaluation is to assess the quality of lower-order latent constructs, namely, width (WID), depth (DEP), and innovation (INN). Reflective outer model evaluation involves indicator reliability, internal consistency reliability, convergent validity, and discriminant validity as described by Hair et al. (2012).

We assessed indicator reliability using two criteria: the indicator loadings for all items ranged from 0.916 to 0.974 and were highly significant (p<0.001), exceeding the required threshold of 0.7 (Hulland and Business, 1999) (Table 10); the squared multiple correlation (SMC) for the indicator, that is equal to the squared of the completely standardizing loading in models where each indicator loads on only one construct (MacKenzie et al., 2011), ranged from 0.839 to 0.949, well above the recommended cutoff of 0.5 (Bollen, 2014) (Table 10). These results suggest that the test of indicator reliability was met.

Internal consistency reliability is ensured when the composite reliability (CR) scores are higher than the cutoff of 0.7 (Fornell and Larcker, 1981). Table 11 shows that the smallest CR was 0.948. Moreover, the average variance extracted (AVE) scores ranged from 0.858 to 0.938 (Table 11), well exceeding the threshold of 0.5 (Fornell and Larcker, 1981) and implying convergent validity.

Item	Item description	Loading	P value	SMC
Width				
WID1	I know internal relationships among different modules of ERP system.	0.916	<0.001	0.839
WID2	I have ERP knowledge of other business processes related to my job.	0.929	<0.001	0.863
WID3	I know ERP operations of other users who are related to my job.	0.933	<0.001	0.870
Depth				
DEP1	I know how business processes are implemented in ERP system.	0.957	<0.001	0.916
DEP2	I know how business processes and ERP system integrate together.	0.943	<0.001	0.889
DEP3	I know how business processes run in ERP system.	0.954	<0.001	0.910
Innovation				
INN1	I have provided suggestions to adjust ERP system to better fit our business processes, and my suggestions were adopted.	0.960	<0.001	0.922
INN2	When changes happen in business processes, I have provided suggestions about how to solve them in ERP system, and my suggestions were adopted.	0.972	<0.001	0.945
INN3	When new business processes appeared, I have provided suggestions about how to solve them in ERP system, and my suggestions were adopted.	0.974	<0.001	0.949

Table 10. Indicators reliability validation

Construct	CR	AVE	Correlations		
			WID	DEP	INN
WID	0.948	0.858	0.926		
DEP	0.966	0.905	0.718	0.951	
INN	0.978	0.938	0.667	0.767	0.968

Table 11. Lower-order construct validation

Item	WID	DEP	INN
WID1	**0.916**	0.686	0.648
WID2	**0.929**	0.638	0.587
WID3	**0.933**	0.669	0.616
DEP1	0.695	**0.957**	0.700
DEP2	0.658	**0.943**	0.752
DEP3	0.696	**0.954**	0.738
INN1	0.649	0.743	**0.960**
INN2	0.642	0.738	**0.972**
INN3	0.647	0.749	**0.974**

Table 12. Item loadings and cross-loadings

We tested discriminant validity using two measures. First, each construct's square root of AVE should be higher than its correlation with any other construct (Fornell and Larcker, 1981). The right part of Table 11 displays construct correlations and square roots of AVE on the diagonal. The smallest square root of AVE value was 0.926 (WID), while the largest correlation was that between depth and innovation (0.767). Second, each indicator should load highest on the construct it is intended to measure (Chin, 1998). Table 12 shows that the indicator loadings on their own construct were notably higher than their cross-loadings on any other construct. Therefore, all conditions of discriminant validity were met.

5.4.4 Evaluating Inner Model

The outer model evaluation provides evidence of reliability and validity, it is thus appropriate to examine inner model estimates. Inner model assessment involves six criteria, including R^2, path coefficient estimates, effect size, multicollinearity, and adequacy coefficient (R_a^2) (Hair et al., 2012, Edwards, 2001).

R^2 is used to assess the inner model's predictive accuracy (Hair et al., 2012). Since the indicator reuse approach was used for the measurement of individual level ERP assimilation, all variance of individual level ERP assimilation is explained. As a result, the value of R^2 is around 1 (Table 13).

Path coefficient estimates provide evidence of the quality of inner model (Hair et al., 2012). As Table 13 shows, all path coefficients were significant (p<0.001), implying that individual level ERP assimilation is explained by width, depth, and innovation. Further, we estimated the absolute contribution of the three lower-order constructs served as formative indicators to higher-order individual level ERP assimilation by examining their effect sizes (Bollen, 2014, Hair et al., 2012). Cohen et al. (2013) has recommended a strong effect cutoff level of 0.35, a moderate effect level of 0.15. The similar effect sizes of depth (0.351) and innovation (0.352) indicate that they have similarly strong effects on individual level ERP assimilation (Table 13), while width has a slightly weaker effect (0.297), but well above the threshold of moderate effects (0.15). These results also confirm the appropriateness of the domain categories that were summarized in the previous case study.

We assessed multicollinearity of the three lower-order constructs for conceptual redundancy. The lower-order

constructs should be distinct, rather than collinear, since they are of a formative nature with regard to individual level ERP assimilation (MacKenzie et al., 2011). We computed variance inflation factor (VIF) to examine multicollinearity (Hair et al., 2012). As Table 13 shows, the largest VIF for the lower-order constructs in relation to individual level ERP assimilation was 2.988 of depth, below the restrictive cutoff of 3 (Petter et al., 2007). Therefore, multicollinearity is not an issue for width, depth, and innovation, implying that we can separate their effects on individual level ERP assimilation.

Higher order construct	**Lower order construct**	**Path coefficients**	***p* value**	**Effect size**	**VIF**	**R^2**	**R_a^2**
ILEA						1.000	0.812
	WID	0.341	<0.001	0.297	2.212		
	DEP	0.381	<0.001	0.351	2.988		
	INN	0.388	<0.001	0.352	2.607		

Table 13. Higher-order construct validation

We evaluated the strength of the relationship between the three lower-order formative constructs and individual level ERP assimilation through the adequacy coefficient (R^2_a), which should exceed the threshold of 0.5 (Edwards, 2001). R^2_a is calculated by summing the squared correlations between the construct and its dimensions and dividing by the number of dimensions (Edwards, 2001). The value of R^2_a was 0.812 (Table 13), indicating that the three lower-order formative constructs include almost important facets of individual level ERP assimilation.

5.5 Step 5: Scale Re-examination

Since the first stage analysis suggests good reliability and validity, we conducted a redundancy analysis, which should be cross-validated on a fresh set of data to assess the validity of the lower-order formative constructs (Ringle et al., 2012, Chin, 1998). We tried to collect more data in the same way as above mentioned. Eventually, we got 91 additional data points, and nonresponse bias tests showed that there were no significant differences between the 91 data and previous 238 data.

In order to perform a redundancy analysis, we created one construct of individual level ERP assimilation. We re-estimated the hierarchical component model in the 1st stage and calculated the latent variable scores of width, depth, and innovation using the 91 data points. The re-examination reaffirmed the reliability and validity of the hierarchical component model. Further, we used the proposed individual level ERP assimilation construct, which was measured with the three latent variable scores as formative indicators, as a causal factor to a second construct of individual level ERP assimilation measured with three reflective indicators (Table 14) (Mathieson et al., 2001, Cenfetelli and Bassellier, 2009). We estimated the causal model in WrapPLS. The strength of the path coefficient between the two constructs is used to assess the formative indicators' validity, and a magnitude of ideally 0.9 or at least 0.8 is desired (Chin, 1998). As the results in Figure 3 show, the value of the path coefficient was 0.881, suggesting the strong validity of the three formative indicators of individual level ERP assimilation.

Construct	**Item**	**Item description**
Individual level ERP assimilation	ERP1	I'm good at ERP usage.
	ERP2	I'm proficient in ERP system.
	ERP3	I'm superior in terms of using and understanding ERP system.

Table 14. Global item generation

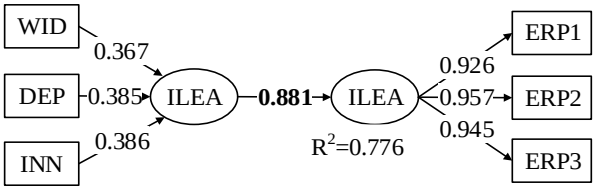

Figure 3. The results of the redundancy analysis (All path coefficients are significant at the 0.001 level.)

Overall, the results of the comprehensive analysis of our hierarchical component model and the redundancy analysis provided sufficient evidence of the reliability and validity of the proposed measurement instrument for individual level ERP assimilation.

6 DISCUSSION

We developed and validated a measurement instrument to assess three key dimensions of individual level ERP assimilation. The feedback from the broad range of ERP users involved in the multi-case study provided convincing evidence of three formative dimensions of individual level ERP assimilation and suggested that our

conceptualization of width, depth, and innovation have content validity. Based on the rigorous instrument-development process and the confirmed reliability and validity, we concluded that we have developed a comprehensive instrument to measure and a multidimensional view to understand individual level ERP assimilation.

This study extends ERP assimilation research by developing and validating an individual level ERP assimilation measurement model with three formative dimensions (i.e., width, depth, and innovation). Specifically, this study contributes in several ways to extant research on ERP assimilation. First, it defines three formative dimensions of individual level ERP assimilation. Previous research defined individual level ERP assimilation as a single construct (Liu et al., 2011), while this study refines it into sub-dimensions, which helps advance our understandings of individual level ERP assimilation. Second, this study extends the diversity and depth concepts of Liang et al. (2007) from organization to individual level with specific measurement items. Third, this study refines the concept of "innovative use" of technology (Li et al., 2013) by individual users in the context of ERP systems. Fourth, our measurement instrument enables the assessment of the degree of ERP assimilation of individual users, and makes individual level ERP assimilation become an operationalized variable for empirical research, not just a conceptual definition. Moreover, this study develops measurements for the three formative dimensions, which opens up a new research area for individual level ERP assimilation. Finally, the instrument development and validation procedure we applied to develop and validate a measurement instrument for individual level ERP assimilation involves a multi-study methodology that demonstrates the importance and usefulness of exploratory case study in measurement development and validation processes.

Our research also has meaningful implications for practitioners. First, through the development and validation of the instrument, we provide a reliable and valid measurement instrument for management to assess how well their ERP users have assimilated the ERP systems. Managers can use the instrument to analyze the assimilation level of every user, and, through comparing individual assessment results, find the problematic areas in their use of the ERP systems, and take targeted measures to improve the overall level of ERP assimilation in their firm. Second, the three dimensions of individual level ERP assimilation also have implications for human resources management. Managers can develop strategies for talent cultivation and development according to the business need for ERP systems. For example, if depth is more important to some positions or tasks, then managers could foster specialists. On the other hand, if width is more important, then managers could focus on developing generalists.

Several limitations are worth noting. First, this study was conducted based on users of ERP products in China. However, the dimensions and measurements of individual assimilation in different countries and regions may vary. Replication in other countries with different ERP products could further improve the reliability and validity of the measurement model. Second, in our formative measurement model, the three dimensions predicted about 0.78 of the variance in the reflectively measured individual level ERP assimilation, showing a good content coverage. However, it also suggests that there are likely unidentified dimensions of individual level ERP assimilation, which needs future research to explore.

7 CONCLUSION

In this study we developed and validated an instrument for assessing ERP assimilation level of individual users in organizational setting. In doing so, this study contributes to the body of knowledge of individual level ERP assimilation by introducing three dimensions of individual level ERP assimilation. Our result enables researchers to conduct empirical studies to evaluate and benchmark ERP assimilation within and across organizations. This study also advanced scale development methodology by combining case study with instrument development procedures. The instrument developed in this study provides opportunities for practitioners to assess and compare the level of assimilation of ERP systems in their organizations, and enables scholars to conduct a new range of theory-driven empirical ERP assimilation studies.

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