



Corvinus University of Budapest
Doctoral School of Business
Informatics

DOCTORAL DISSERTATION

Summary

Muhamet Gërvalla

**A maturity model for implementation and
application of Enterprise Resource Planning
systems and ERP utilization to Industry 4.0**

Supervisor: Katalin Ternai, PhD

Budapest, 2020

Department of Information Systems

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Contents

I.	Research background and justification of the topic	4
I.1	Aims and objectives.....	7
II.	Methodology;.....	9
II.1	Model validation.....	11
III.	The findings of the dissertation	14
IV.	Main references.....	28
V.	List of publications	31

I. RESEARCH BACKGROUND AND JUSTIFICATION OF THE TOPIC

There are many solutions that information technology offers in support of the organizations to manage their business processes to integrate data deriving from the managerial level to production, such as Enterprise Resource Planning systems. The implementation and application of Enterprise Resource Planning (ERP) support the organizations in managing their resources, processes, and to integrate all the business processes into a single unified platform. ERP systems assist an organization in many areas starting from increasing better information sharing between departments, improving workflow, better supply chain management, integration of data, processes, and technology in real-time across internal and external value chains (Shang and Seddon, 2002; Mabert, Soni and Venkataramanan, 2003; Thomas F. Gattiker, 2005). ERP system application increases

the information flow between the departments or business units worldwide, as well as collaboration with partners, suppliers, and customers.

On the other hand, Industry 4.0, as a new technological concept, aims to support organizations to complete digitalization and automation of their processes and functions, specifically in the manufacturing industry. This generation enables computers and automation connectivity by using IoT devices, starting from suppliers, distributors and manufacturing facilities, a stage when robots and machines have begun to replace human workers and also collaborate with them (Haddara and Elragal, 2015; Forbes, 2016).

Based on the previous studies, it is confirmed that the organizations are struggling with the process of implementation and application of the ERP systems. At least 30% of the organizations that have implemented and are applying ERP systems still do not know if they succeed in the implementation and application of the ERP system.

Many studies have identified critical success factors that have an impact on the implementation and application of ERP, while the implementation and application is classified into different frameworks proposed by different researchers. In support of the organizations, to evaluate the maturity of implementation and application of ERP system, there are identified three ERP maturity models, but they are very complex to be used by the organizations, and lack on defining the complete process of assessment, which supports the organizations to check their maturity level of ERP by themselves. Considering the mentioned points, new technological changes and the need of the organizations for further digitalization, there was a need to develop a maturity model that supports the organizations in the evaluation of their position regarding the ERP system maturity on their organizations.

This study analyzes the evolution of ERP systems and the current trends of their implementation and

application, also the organization's readiness for further digitalization based on the developed ERP Maturity Model.

I.1 Aims and objectives

The overall aim of this thesis is to analyze challenges, as well as to identify crucial elements of ERP systems implementation and application. Based on the undertaken study, a new maturity model for ERP system implementation and application will be developed. At the same time, the research will try to understand the relationship between different stages of ERP implementation and application, business performance, and Industry 4.0.

Objectives of this thesis are:

- To create a theoretical background of ERP lifecycle and models to measure the maturity level of ERP systems implementation and application;
- To create a maturity model for ERP systems implementation and application;

- To determine the relationship between different stages of implementation and application of ERP systems;
- To assess the effect of ERP application on business performance;
- To develop a prototype to measure the ERP maturity;
- To create a theoretical background of Industry 4.0;
- To define the challenges to integrate ERP and Industry 4.0.

II. METHODOLOGY;

In order to achieve the aims and objectives of the study, the following steps are applied to layout the design, development and implementation of the methodology.

- Identification of the research undertaking;
- Literature review;
- Problem statement;
- Definition of the research aims and objectives;
- Definition of the research methodology;
- Development of the research methods and research instruments;
- Design of the questionnaire;
- Data gathering through the survey;
- Verification of data reliability and validity;
- Data processing and analysis;
- Results assessment and analyzes;
- Conclusions, contributions, and research recommendations.

The literature was collected from electronic databases, like ScienceDirect, EBSCO, SpringerLink, and other databases with a focus on Information Systems, Computer Sciences, and Business Management. The Webster and Watson approach for literature review served as an appropriate approach for gaining comprehensive insights (Webster and Watson, 2002). Also, opinions from the industry and reports are considered even that the study is purely academically based. Primary data collection is done by using a questionnaire and quantitative research methodology. The questionnaire is developed to collect the data from organizations in support of model validation. To design and develop the questionnaire, the Dillman approach was applied (Dillman, 2007). In order to check the questionnaire's reliability, initially, it was sent to 19 organizations, and based on them, the questionnaire is analyzed and approved for further investigation of the problem. There were 91 responders collected

from organizations that already have implemented and are applying ERP systems. Various management levels in the organizations took part in the study. The research was undertaken in different industries such as Wholesale & Distribution, Manufacturing, Retail ICT, Professional & Financial Services, Public Sector, Education, Healthcare. Also, the size of the organization was classified by the number of employees, where 34.07% of responders were from organizations with 50 – 249 employees, 31.87% with 10 – 49, 29.67% with 250 and more employees while the rest of the organizations are classified with 1 - 9 employees.

II.1 Model validation

For the purpose of examination of the reliability and validity of the model, the following analysis has been done: Average Variance Extracted - AVE, Cronbach's alpha, Composite Reliability, and Loading factor. Below are presented the results of the analysis. The two-stage approach for data

analysis using SEM proposed by Gerbing and Anderson was applied (Gerbing and Anderson, 1988). At the first stage, a measurement model was estimated using Confirmatory Factor Analysis (CFA). In the second stage, Structural Equation Modeling (SEM) was used to test the significance of the relationship of variables. At the first step measurement model was estimated using all 40 items. The goodness of fit index of the initial model (GoF index) was 0.53 that was between 0.45 to 0.9 that is considered as a range of the GoF index for a true model (Evermann and Tate, 2010). To improve the model, according to Awang, items that have loading < 0.6 were removed one by one, then again, the analyses were done until all items loadings have values larger than 0.6, indicating that the model has no “problematic items”. Internal consistency of constructs was investigated using Cronbach Alfa and Composite Reliability Statistics Omega. All the values of Cronbach’s α , ranged from 0.84 to 0.88, exceeding the level 0.7 that

proves the internal consistency of all latent constructs is acceptable. Also, all the values of Composite Reliability Statistics Omega were more than the threshold 0.70, which is considered as an acceptable level. Thus, all values of ω support construct reliability of the model for all latent variables. Convergent Validity of the model is estimated with Average Variance Extracted, where all the values exceed the acceptable level 0.5. Discriminant Validity was investigated by correlation matrix where all the coefficients between constructs were smaller than threshold 0.85, which proves no significant overlap between the constructs exists. Thus, the goodness of fit index of the final model (GoF index) is 0.55 that meets the range of 0.45 to 0.9 for the true model (Evermann and Tate, 2010). The final version of the model has 35 variables and five constructs.

III. THE FINDINGS OF THE DISSERTATION

The proposed ERP Maturity Model (ERPMM) to measure the maturity of ERP systems implementation and application has been developed in full harmony with the literature review that has been done in this study through the use of secondary data and validated with primary data. The model to measure the maturity of ERP systems implementation and application (ERPMM) consists of 5 constructs, as shown in Figure 1. The model constructs are:

1. Strategic use of IT;
2. ERP Selection;
3. ERP Implementation;
4. ERP Application;
5. Performance Indicators.

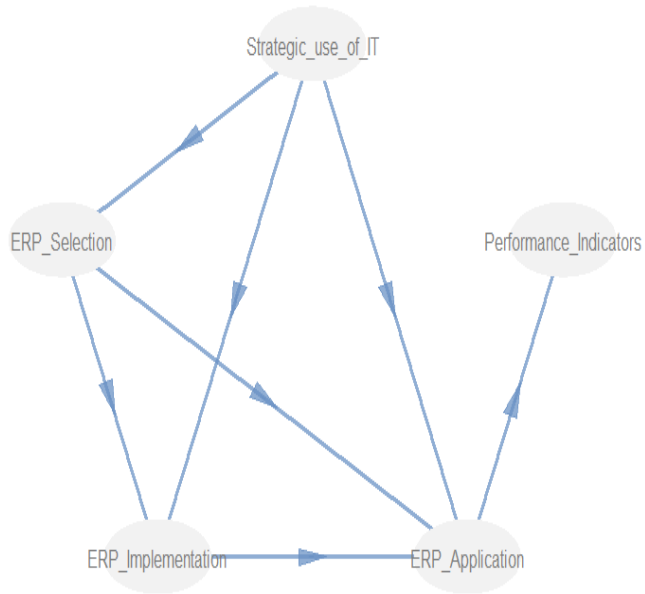


Figure 1 ERP Maturity Model (ERPMM)

With the application of the presented maturity model – ERPMM and the calculated weight for each of the items of the constructs of the model, now it is manageable to determine the maturity of the ERP implementation and application of the organizations. In order to determine the classification of ERP maturity, the CMMI approach

with a five-level classification will be applied.

Level I - Non-Compliant: the organization did not achieve the essential criteria for the implementation and application of the ERP system. There are many critical issues that the organization faced during this process;

Level II - Substantially-Compliant: the organization lacks on the implementation and application of ERP systems, even that there is a minimal positive impact on this process.

Level III - Partially-Compliant: the organization started to identify the impact in some aspect of implementation and application of ERP system even that what was achieved it is not enough;

Level IV - Compliant: the implementation and application of the ERP system resulted in the integration of organization functions and positive feedback on all levels where the ERP is applied. The organization achieved to create a stable system in support of the organization stability;

Level V - Fully-Compliant: the organization acts

entirely in accordance with the initial strategic plan for implementation and application of the ERP system, furthermore the organization is ready for further digitalization or new technologies implementation and application.

The answers to the research question of the study are presented below:

Research Question 1 - What is the relationship between ERP selection, ERP implementation and ERP application with the organization's IT Strategy?

During this study, there are identified factors that are important during the definition of the organization's IT strategy and also for ERP selection, implementation and application. Top management support for investing in IT projects was one of the factors that is identified as the critical point during the IT strategy development. Also, the involvement of employees as a stakeholder is considered another critical factor, while for the planned project, it is essential also

that feasibility studies should be done in order to check if the organization has technical and human resources to support the implementation of the IT projects. For the ERP projects, it is essential that there should be cross-department cooperation to support smooth and effective business processes to ensure that the requirements for ERP implementation can be carefully defined based on the organization's culture. The aim of the organization for ERP implementation and application should be defined clearly in IT strategy by developing the vision of ERP implementation and followed by a cost-benefit analysis for ERP implementation and application which is vital as an initial point before starting this process. In order to validate if the mentioned points of IT strategy regarding the ERP implementation and application and if there is a relationship between IT strategy and ERP selection, implementation, and application, one main hypothesis and two sub-hypotheses, H1 - Strategic use of IT significantly

and positively affect ERP Implementation, H1.1 - Strategic use of IT significantly and positively affects ERP Selection, and H1.2 - Strategic use of IT significantly and positively affects ERP Application, were generated. Based on the results of the hypotheses testing, it is confirmed that: Strategic use of IT significantly and positively affects ERP Selection; Strategic use of IT significantly and positively affects ERP Implementation; Strategic use of IT significantly and positively affects ERP Application.

Research Question 2 - What is the impact of ERP selection on ERP implementation and ERP application?

To assess the impact of ERP selection on ERP implementation and application, based on the literature review, the critical success factors that affect this process are identified. During the ERP selection, there are categorized many factors that must be considered. For the purpose of selecting factors that have the highest impact, only those

who are mentioned mostly by researchers are selected. Based on this, it is crucial that during the ERP selection, the evaluation team should have full support on this process, also the necessity to involve in the team the management and user's representative as key stakeholders for the ERP application. The ERP vendor and implementation partner portfolio in terms of technical and financial capacities, also the solution that ERP vendors offer and their expertise to understand the organization culture and industrial norm where the organization operates are important factors that must be considered during the ERP selection. Also, the selected ERP vendor requirements for hardware and infrastructure should be in line with the investing capacities of the organization. Based on factors for ERP selection and for the purpose of validation of these factors and to answer the research question, the following hypotheses were generated: main hypothesis H2 - Appropriate ERP Selection has a positive impact on ERP Application

and sub-hypothesis H2.1 - Appropriate ERP Selection has a positive impact on ERP Implementation. After testing these hypotheses, it is confirmed that appropriate ERP Selection has an impact on the ERP implementation and ERP application.

Research Question 3 - Does the ERP implementation have an impact on the ERP application?

Many previous studies have stated that the decision for implementation and application of an ERP system is related to the strategy of the organization by determining the aims and objectives they want to achieve for a period of time. Based on this study, it is identified that definition of scope and clear objectives by the implementation team and the ability of them to bridge the gaps between the existing workflow and new ERP business practices should be well considered during the implementation and application of the ERP system. Also, the organization should be prepared to accept

the changes for the best practices for the new ERP system during the implementation in order to eliminate the problems when the ERP system goes live. Another factor that is important during the implementation is employee training for the new system usage and operation, while the implementation of the project in time, planned budget, and the selection of appropriate implementation technology affects the success of the implementation. Considering the above-mentioned factors, in order to answer the research question, hypothesis H3 - ERP Implementation has a significant and positive impact on ERP Application has been generated. Based on the literature review and hypothesis testing, it is validated that ERP implementation has an impact on the ERP application.

Research Question 4 - Is there any significant evidence that ERP application has a positive impact on organization performance?

As it is stated in the literature review, the ERP application can support the organization's benefits from these systems in many areas, which are presented on the sub-chapter of the Benefits of ERP application. In order to evaluate the success of the ERP application, the most mentioned factors identified by previous authors are considered. One of the main factors is if the organization achieved the goals and objectives they had when they decided to implement and apply an ERP system, followed by the support of ERP application in the automation of business processes and functionalization and reducing the manufacturing or service offering time. Also, ERP application should support the digitalization and integration of communication between the departments in order to increase the efficiency and do an easier job for the employees. At the same time, the organization should be adopted with the new business changes and their new business process based on the ERP application to support people, technology, and

organization culture. Based on the mentioned factors that affect the ERP application and the generated hypothesis H3.1 - ERP Application has a positive impact on Performance Indicators, it is confirmed that ERP application significantly affects the organization's performance.

Research Question 5 - What is the impact of Industry 4.0 on the ERP systems approach?

The study identifies the challenges of integration of current ERP systems with Industry 4.0. Furthermore, based on the findings, there are many challenges related to the integration of Industry 4.0 and current ERP systems, especially when it comes to machine to machine, machine to ERP communication, and the security of the data. Because there are different ERP vendors and a diversity of devices and technologies that are a must to be interconnected, the ERP system vendors should think about finding solutions and creating protocols that will support the integration of technologies in support of Industry 4.0. In support

to answer to this question, a hypothesis is generated, H4 - ERP Application can support organizations to evaluate their readiness for Industry 4.0, to understand if ERP application could support the organizations for further digitalization, specifically for Industry 4.0 technologies. The result of H4 hypothesis testing is accepted.

Based on the proposed maturity model, it is developed a prototype that supports the organization to evaluate its status of ERP system implementation and application. The prototype is a Web Application, and it is developed in PHP and MySQL database.

The main contributions of this study are:

- Identifies and presents the current status of implementation and application of the ERP system and ERP maturity models;

- Analyzes the role of strategic use of IT in the process of ERP selection, implementation, and application;
- Analyzes the impact of ERP selection on implementation and application also the effect of ERP implementation on the application;
- Identifies the ERP application effect on business performance also the ability of the organization to evaluate their readiness for further digitalization based on the ERP application;
- A new ERP Maturity Model (ERPMM) to support the organizations for evaluation of implementation and application of the ERP system is developed;
- A developed prototype that applies ERPMM to support organizations for ERP maturity level assessment.

The work that has been done during this research

will support the organizations to understand or investigate where they stand in relation to the ERP system implementation and application and does this investment achieves what they planned on their organization strategy. On the other hand, a successful ERP implementation and application which could be measured with the usage of proposed ERPMM supports them on decision making for further digitalization of their organization. It is important that ERP vendors should add new services to their ERPs towards Industry 4.0.

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