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Edward W.N. Bernroider

Royal Holloway, University of London, Edward.Bernroider@rhul.ac.uk

Frantisek Sudzina

Copenhagen Business School, frantisek@sudzina.com

Andreja Pucihar

Faculty of Organizational Sciences, University of Maribor, Andreja.Pucihar@fov.uni-mb.si

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European criteria for assessing enterprise resource planning (ERP) systems: Preliminary results from multiple empirical studies

Edward W.N. Bernroider

Royal Holloway, University of London, School of Management, United Kingdom
Edward.Bernroider@rhul.ac.uk

Frantisek Sudzina

Copenhagen Business School, Denmark
fs.caict@cbs.dk

Andreja Pucihar

Faculty of Organizational Sciences, University of Maribor, Slovenia
Andreja.Pucihar@fov.uni-mb.si

Abstract

This research report provides preliminary results in terms of ERP system selection criteria across five European Union countries based on empirical studies. The paper provides a structured list of decision making criteria considered in ERP decisions and contrasts weights as well as achievement levels across countries. Research was guided by the Delone & McLean Information Systems (D&M IS) success model supported with views on project and vendor related aspects needed to capture the whole scope of the decision problem. The main considered dimensions were: quality; net benefits; project costs and time; and a vendor dimension. Especially the considered dimensions from the D&M IS success model, namely quality and net benefits varied across countries in terms of their initial weighting and satisfaction levels achieved after ERP implementation. However, a common global notion seems to be that quality and project related criteria are more important to the decision maker than potential benefits on the organisational or individual level.

Keywords: Enterprise resource planning (ERP) system, Evaluation, IS performance, Empirical study, DeLone and McLean model

1 Introduction

This research paper targets the area of complex technology selection, project facilitation and connected level of satisfaction achievements for the case of enterprise resource planning (ERP) systems based on a multi-national study within the European Union. The paper acknowledges the importance of ERP systems while appreciating potential diversity and multi-vocality leading to different assessment profiles and project outcomes within the European Union.

ERP systems can be seen as generic software which is adaptable by customization (parameterization of data tables) without a great deal of programming efforts. The systems consist of an integrated set of software modules supporting core business processes, such as production, logistics, finance and accounting, sales and marketing, and human resources. With pre-configured templates, ERP systems target an anonymous market. Besides integration, the aim is to enhance decision support, reduce costs, receive more accurate and timely information, higher flexibility or increased customer satisfaction (Kremers, Dissel, 2000; Mabert et al., 2000). ERP packages are complex and “fat” software applications with corresponding difficulties in their implementation as expended efforts for selection and implementation show. An empirical analysis of the implementation process in European firms revealed mean implementation costs of EUR 5 Mio. and a mean implementation time of 13.5 months (Buxmann, König, 1997). A more recent survey reported that ERP implementation may cost millions of USD (Jutras, 2007). In addition, also high risks are involved in every ERP project. ERP implementations can have adverse effects on the firm as shown by many examples (Bingi et al., 1999; Buckhout et al., 1999; Scott, 1999) show. A market research company reported that 70% of ERP implementations fail to achieve their corporate goals (Buckhout et al., 1999). Hence, ERP projects do regularly not conform to quality, costs and time objectives. A natural assumption is that these projects have not been adequately assessed in the early project stage of decision making. Although a considerable amount of articles contribute towards analysing the value of information systems, packaged software solutions or commercial off the shelf (COTS) products (Muschter, Österle, 1999, Ward, Taylor, Bond, 1996) in general, only a few have focused on the special case of ERP systems. According to (Keil & Tiwana, 2006), very little has been written about ERP system selection criteria in academic journals.

Our research aim is to further develop the literature concerning ERP decision making criteria in a multi-national context and as our main objective to make conclusions in terms of achieved ERP net benefits according to the structure of the Delone and McLean IS success model. Based on primary data analysis our detailed research objectives are:

- (i) To provide a structured list of ERP selection criteria;
- (ii) To provide a framework for understanding criteria and their causal relationships;
- (iii) To contrast the importance of ERP system criteria across countries;
- (iv) To contrast the level of achieved satisfaction with ERP systems in terms of assessment criteria across countries.

To answer these questions, this article draws on data gathered from different independent, empirical surveys undertaken in the EU member states Austria, Slovenia, Slovakia, Denmark, and the U.K. Hence, results should be, for the most part, applicable

to the fifteen member states that constituted the union until 2004/05/01 and also to the new ten member states.

The paper is structured as follows. The following section will provide a short overview of the quantitative method including the conducted ERP selection criteria studies. This is followed by a section developing the decision making criteria list from literature which is consequently processed into a research model. The model was used to highlight the preliminary empirical results in the following section. The last section concludes the paper.

2 Research method

The paper presents a literature-based discussion on ERP selection criteria building on the work of Bernroider and Koch (E.W.N. Bernroider, Koch, 2001) with a focus on multiple criteria oriented approaches. The resulting list supports research objective (i) and was used in a number of different nationwide primary empirical surveys. The surveys considered small to medium sized enterprises (SMEs) and large enterprises. To avoid under representing the large enterprises in the samples all studies used a stratified and disproportional sample with subgroups according to company size. The Austrian and the UK companies were randomly selected from firms listed in a comprehensive, pan-European database containing financial information on 7 million public and private companies in 38 European countries (Bureau-van-Dijk, 2003). The Slovakia and Slovenian enterprises were randomly selected from the lists of firms provided by respective Statistical Bureaus. The Danish companies were randomly selected from a company database containing information on all VAT registered Danish companies called CD-Direct. The following table presents the independent empirical surveys with their key characteristics.

Country	Year	Initial sample size	Response rate
AUT	2003-4	1000	22%
DEN	2007	1200	1.75%
SLK	2007	1200	9.33%
SLV	2007	1200	7.5%
GBR	2003	1000	2.1%

Table 1: Overview of survey characteristics

The questionnaire was guided by descriptive and analytical research goals, in particular, concentrating on ERP system selection and assessment, as given in this paper. It was derived from the one used in (E.W.N. Bernroider & Koch, 2001). Following an empirical design method, a research panel was asked to critique the questionnaire for content validity (Dillman, 1978). According to their suggestions, the questionnaire was revised and used in Pre-Tests applied in the UK and Austria. Responses were examined to optimise the formulation of each question and to ensure consistency in the way they were answered. The questionnaire contained a general section assessing the background information on the company especially IT/IS related and performance related questions. All criteria were assessed through equally oriented 5-point Likert interval scales to avoid misconceptions as given in the next section (1 stands for a very low and 5 for a very high perceived importance or achieved satisfaction with ERP system criterion). To

test for non-response bias, known distributions of three variables available through the used corporate database (legal form, number of employees, number of subsidiaries) were assessed. The analysis revealed no significant different characteristics between non-respondents and respondents in terms of these three aspects as measured by chi-square (χ^2) and two-sample unpaired t tests.

The data was analysed using a statistical package offering the ability to work on complex samples. It should be noted that in practice, most scientific papers utilize the default significance tests generated by software packages based on the assumption of simple random sampling even if multi-stage, cluster, or other complex sampling designs were employed (Choudhry & Valliant, 2002; Kish, 1992; Korn & Graubard, 1995). To avoid biased estimates, this work uses a SPSS module called Complex Samples where adjusted tests including chi-square (χ^2) are provided. However, since the range of procedures is limited, analysis was also conducted with the use of sampling weights (Purdon & Pickering, 2001). For comparison of the independent samples that were not normal distributed (tested using Kolmogorov-Smirnov), a Kruskal-Wallis test was employed.

3 ERP selection criteria

ERP systems per se received a lot of attention in the last years; there are many ERP systems research instances and quite a lot of reviews, e.g. (Esteves & Pastor, 2001), (Shehab et al., 2004) and (Botta-Genoulaz et al., 2005). However, the selection of ERP system, as a distinct field of research, seems underrepresented. We looked at articles from journals covered in Web of Science to confirm this view and received the following distribution (see Figure 1) of articles over time. There are 58 articles, which looked at ERP system selection, out of 404 articles on enterprise resource planning. Only 22 out of these 58 articles mention selection criteria.

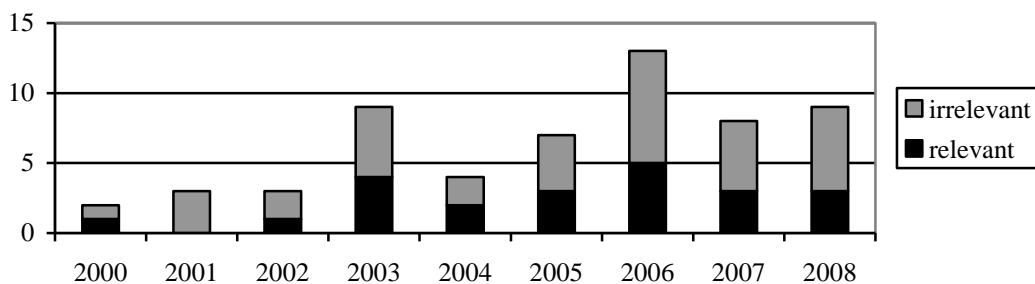


Figure 1: Distribution of articles on ERP and selection

Other research confirms that very little had been written about packaged software selection criteria in academic journals (Montazemi et al., 1996). Keil and Tiwana only found three scholarly publications on the subject (E.W.N. Bernroider, Koch, 2001), (E.W.N. Bernroider, Koch, 2001), and (Keil, Tiwana, 2006). The article issued by (Baki, Cakar, 2005) is one of the first journal articles working with a comprehensive list of selection criteria and became the source for many other work on multiple attributive based ERP selection (Keil & Tiwana, 2006). Another research effort exploiting this list of criteria was conducted in Turkey (Baki & Cakar, 2005). The study on Turkish firms aimed at filling the gap resulting from the scarcity of studies on ERP selection criteria.

The authors used criteria lists from seven different sources to identify 17 main criteria for their analysis on importance levels. In this paper we refer back to the original list from Bernroider and Koch with a few modifications in terms of technical aspects. The “Year 2000” criterion (relating to the dreaded millennium bug) for example was an important aspect at the time but is not relevant for more recent studies. Table 2 shows the 28 selection criteria used in this research project.

ID	Criteria	ID	Criteria
1	Systems reliability	15	Increased organisational flexibility
2	Functionality of the system	16	Enhanced Decision Making
3	System flexibility	17	Reduced cycle times
4	Advanced technology	18	E-business enablement
5	System interoperability	19	Business process improvement
6	Operating system independency	20	Enabler for desired business processes
7	Connectivity	21	Increased customer satisfaction
8	Availability of a industry focused solution	22	Improved innovation capabilities
9	Organizational fit of system	23	Enabling technology for CRM, SCM, etc.
10	Internationality of software	24	Costs expended
11	System usability	25	Short implementation time
12	Integrated and better quality of information	26	Vendor reputation
13	Incorporation of business best practices	27	Vendor support
14	Improved service levels/quality	28	Market position of vendor

Table 2: Overview of selection criteria

4 Research framework

The assessment of economic and organizational aspects related to technical developments is known as difficult task (Brynjolfsson, 1993). There exists a number of models that examine how firms develop IT capabilities (Zheng et al., 2004), e.g., the models proposed by Venkatraman (Venkatraman, 1991) comprising five levels of IT-induced reconfiguration, the transporter model (Levy & Powell, 2003) focusing on business growth and business value, the focus-dominance model based on different approaches to IT adoption, e.g. adoption for collaboration support (Levy et al., 2001). The mentioned models concentrate on the rationale behind IT adoption but do not provide a holistic picture of achieved project success. In this matter and with regard to the adoption of specific IT technologies in SMEs, research provided a limited spectrum of results. More studies that adopt and apply evaluation models that can measure ERP success, in particular, for on-going evaluations are needed. The popular DeLone and McLean (D&M) IS success model (DeLone & McLean, 1992), which the authors revised 10 years later (DeLone & McLean, 2003), can be described as comprehensive multi-dimensional approach to assess IS success. The original model was drafted to synthesize work involving individual measures into a single coherent model. The model contains the following six IS success perspectives that were proposed to be interrelated rather than independent:

- (1) “system quality”, (2) “information quality”, (3) “use”, (4) “user satisfaction”, (5) “individual impact”, and (6) “organizational impact”.

Based on a large number of research contributions since the original model was published (referenced already in over 300 articles in refereed journals), the authors have revised their first concept. Quality was postulated as a three-dimensional construct (“information, systems, and service quality”), each of which should be measured and controlled separately. Those quality dimensions will individually or jointly affect subsequent “use/intention to use” and “user satisfaction”. As a result, certain (positive or negative) “net benefits” will occur (DeLone & McLean, 2003). The net benefits dimension group and all impact related measures can be related to the individual or the firm level.

The DeLone and McLean IS success model was applied in previous work to investigate ERP related projects (Edward W. N. Bernroider, 2008). Bernroider applied the model to investigate the mediating role of IT governance aspects in controlling ERP success. In this paper, we also used the original structure of the D&M model while making some adjustments to account for the decision making setting. The quality assessment was combined into one dimension rather than looking at three different ones (Service, Information, and System). This reduction does not limit the model but helps to avoid ambiguity of quality criteria between the sub-groups. The middle dimension “Intention to use/use and user satisfaction” can not be easily assessed in terms of decision making criteria and did not contribute to the list of decision making criteria for ERP (therefore shaded in the model). However, the middle dimension has a mediating role for driving the involved net benefits, the final dimension of the model. Empirical research has provided evidence on the validity of these causal relationships (Livari, 2005). In addition to these aspects, more implementation and also vendor related groups were needed to find sensible links to criteria identified in ERP system decision making (see Table 2). For this purpose we considered vendor’s characteristics and the missing dimensions of the “Iron Triangle” in project management (Jha & Iyer, 2007), namely Time and Costs. While the former is an exogenous factor that can be taken into account in terms of decision making criteria, the latter two are endogenous aspects that should be considered in terms assessing the impact of ERP systems in terms of delivering the needed major organisational change. The final model closely resembles a measurement model developed and applied specifically for ERP system success assessment (Edward W. N. Bernroider, 2008). The quality dimension was again perceived as having an effect on net benefits, which was facilitated by IT governance mechanism in this paper.

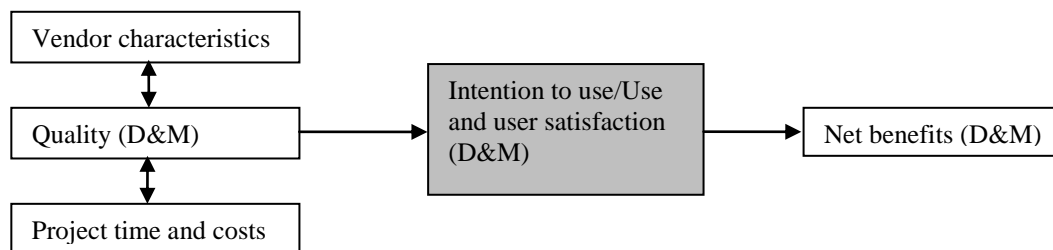


Figure 2: Research model for criteria assessment and classification

The research model allows us to assign dimensions to criteria and to exploit the causal connections in the underlying models for discussing cause and effect relationships. The common ground for all factors in the model is their application as decision making attributes in ERP decisions. Prior research has used some of them in IS success models

such as the mentioned DeLone and McLean’s IS success model. Others, such as costs and time, however, relate to the ‘project’ of implementing ERP systems. The vendor dimension could also be seen as a factor of success or antecedent. Nevertheless, all factors are valid for ERP system decision making and as such are needed to understand decision making criteria. The term ‘net benefits’ implies benefits after deducting project related costs (costs of operating and maintaining the system in the case of an operational IS/ERP). Thus, only by incorporating the additional measures into the basic DeLone and McLean’s IS success model structure, we seem to cover all major dimensions of an ERP decision. This paper utilizes a more holistic conception-centric view of ERP and incorporates business net benefits in the analysis. Each individual selection criterion was consequently assigned to a dimension of our research model (see Table 3).

ID	Dimension	Criteria	ID	Dimension	Criteria
1	Quality	Systems reliability	15	Net benefits	Increased organisational flexibility
2	Quality	Functionality of the system	16	Net benefits	Enhanced Decision Making
3	Quality	System flexibility	17	Net benefits	Reduced cycle times
4	Quality	Advanced technology	18	Net benefits	E-business enablement
5	Quality	System interoperability	19	Net benefits	Business process improvement
6	Quality	Operating system independency	20	Net benefits	Enabler for desired business processes
7	Quality	Connectivity	21	Net benefits	Increased customer satisfaction
8	Quality	Availability of a industry focused solution	22	Net benefits	Improved innovation capabilities
9	Quality	Organizational fit of system	23	Net benefits	Enabling technology for CRM, SCM, etc.
10	Quality	Internationality of software	24	Project costs	Costs expended
11	Quality	System usability	25	Project time	Short implementation time
12	Quality	Integrated and better quality of information	26	Vendor related	Vendor reputation
13	Quality	Incorporation of business best practices	27	Vendor related	Vendor support
14	Quality	Improved service levels/quality	28	Vendor related	Market position of vendor

Table 3. Selection criteria aligned along the dimensions of the research model

5 Empirical Results

5.1 Sample demographics

Following a commission recommendation of the European Communities concerning the definition of micro, small and medium-sized enterprises, this research classified as SME an enterprise which employs fewer than 250 persons and in terms of the Austrian data also an annual turnover not exceeding EUR 50 million. Table 4 shows the distribution of large enterprises (LEs) and SMEs and their absolute numbers in the data sample. We would like to note that sampling weights were used in the statistical analysis to account for our disproportional and stratified sampling technique.

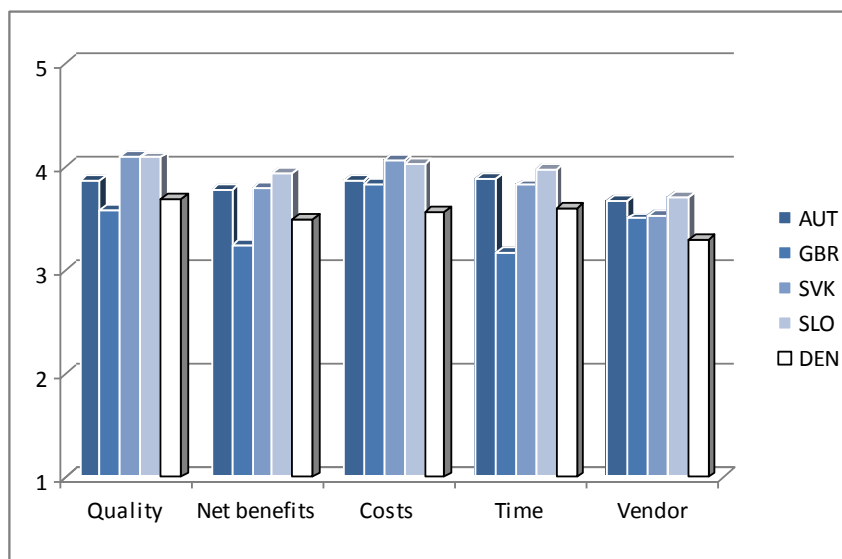
Size	No. of companies (rel. in %)					No. of companies (abs. unweighted N)				
	AUT	DEN	SLK	SLV	GBR	AUT	DEN	SLK	SLV	GBR
SMEs	92.8	94.0	97.6	96.1	0	130	11	61	49	0
LEs	7.2	6.0	2.4	3.9	100	79	10	51	41	20
Total	100	100	100	100	100	209	21	112	90	20

Table 4: Firm size distribution

5.2 Importance of criteria across countries

Table 5 and Figure 3 show the factors of the research model with their mean importance ratings as given by the respondents of the surveys differentiated between countries. As can be seen, quality was regarded as most important in three countries while the cost dimension was most important in the United Kingdom and time in Austria. The vendor dimension did not dominate the decision in any country although different levels of importance were observed. The Kruskal-Wallis non-parametric ANOVA test revealed significant differences when comparing the five samples for each dimension of the model in terms of net benefits and quality ($p < 0.01$). All countries seem to place more importance on either technical quality or project efforts, while putting less weight on net benefits to the organization.

	Mean weights across countries				
	AUT	GBR	SVK	SLO	DEN
Quality	3.87	3.58	<u>4.10</u>	<u>4.09</u>	<u>3.68</u>
Net benefits	3.77	3.24	3.79	3.93	3.49
Costs	3.86	<u>3.83</u>	4.06	4.03	3.56
Time	<u>3.89</u>	3.17	3.82	3.97	3.60
Vendor	3.67	3.50	3.53	3.70	3.29

Table 5. Importance ratings across countries**Figure 3:** Importance ratings across countries

5.3 Achievement levels of criteria

The satisfaction achievement levels were measured in terms of achieved expectations from the viewpoint of the decision maker. Table 6 clearly shows that companies across countries achieved different levels of success. While Austrian, Slovenian and Danish companies seemed very pleased with their vendors, companies from the United Kingdom were most satisfied with achieved quality levels and Slovakian companies delivered their projects best in terms of costs. There seem to be considerable differences in the achievement levels across countries. Austrian and Slovenian companies score very high in every category and seem to view ERP systems more favourably than their counterparts in other countries. Again the Kruskal-Wallis non-parametric ANOVA test was applied and again identified significant differences across countries. Different samples have come from different populations in terms of quality ($p < 0.01$), net benefits ($p < 0.01$), time ($p < 0.05$) and the vendor dimensions ($p < 0.01$).

	Mean achievement levels across countries				
	AUT	GBR	SVK	SLO	DEN
Quality	3.72	<u>3.53</u>	3.19	3.55	3.47
Net benefits	3.46	3.48	2.91	3.43	3.18
Costs	3.34	3.00	<u>3.27</u>	3.49	3.15
Time	3.38	3.00	3.01	3.40	2.73
Vendor	<u>3.93</u>	2.80	3.13	<u>3.73</u>	<u>3.86</u>

Table 6: Achieved expectations across countries

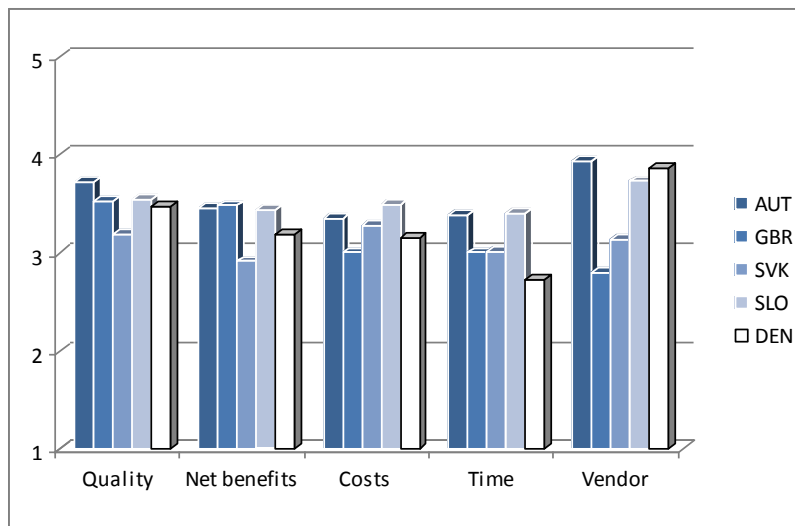


Figure 4: Achieved expectations across countries

6 Conclusions

This research report provides preliminary results in terms of a descriptive oriented overview of ERP system selection criteria across countries in the European Union. The international set-up of this survey seems to be unique. The first objective of this paper was to provide a structured list of global criteria considered in real ERP system decisions. The list of criteria used was deducted from major scholarly articles in the field. The literature review provided support for each of the single criteria. We proposed a base model to structure and group the criteria, which, in essence, was based on the DeLone and McLean's IS success model extended with project related success measures needed for capturing the whole scope of decision making attributes. The major dimensions considered were: quality (the source of the Delone & McLean model), net benefits (the consequences in the Delone & McLean model), costs, time (as the missing Iron Triangle attributes) and the vendor dimension as new factor potentially hindering or fostering success.

The further objectives of this paper were to contrast the perceived importance of the criteria used in decision making as well as achieved ERP satisfaction again relating to the dimensions of the proposed research model highlighting differences across countries. Especially the dimensions from the D&M IS success model, namely quality and net benefits varied across countries in terms of their perceived importance and achieved satisfaction. Reported differences in perceptions seem to reflect different styles and cultures within each of the participating countries although their geographical distances and differences in stages of development are minor. This paper however also supports the view that ERP decision making is dominated by quality and project related criteria across all countries rather than by criteria covering potential benefits on the organisational or individual level. This seems to support the global view that, in business practice, an ERP system seems to reflect a more technical than business led strategy.

This research provides an up-to-date overview of selection criteria and their importance in a multi-national context and provides evidence about different contexts of ERP decision making across countries within the EU. Current limitations are given by the comparability of data in terms of different time scales, return quotas and by the limited number of data sets for individual countries.

Further research will seek to exploit the data gathered to better understand identified structural differences and if reasons for underperforming ERP projects can be identified in the early stage of decision making. More exploratory research is needed, which would analyse how ERP system related benefits develop during ERP system operation, in particular, across countries. With a better understanding of the issues involved in ERP systems evaluations and dynamic benefit development, management (not only in multi-national enterprises) should be better able to make critical decisions, and allocate the resources available and necessary to make ERP system adoptions a success.

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