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A Process Model for ERP Upgrade and Replacement Decisions

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Abstract

Background: *This paper aims to develop an effective decision making (DM) process for ERP change or replacement. ERP in most organizations constitutes a key critical system of high complexity with many stakeholders. A major change activity for such a system therefore exposes an organization to great risks, and thus should be well organized.*

Method: *A design science approach was chosen for this research. Based on a review of related literature and evidence of the DM process at different companies, a general process of DM for ERP upgrade was designed, and later evaluated and improved through a case study approach.*

Results: *The decision process assumes a model with variables describing characteristics and performance of possible alternatives, and the decision is decomposed into steps with three loops that are executed iteratively. We believe that the findings and approach can be useful both for the immediate problem context and also for other IT-related DM problems.*

Conclusions: *The main outcome is the new process of DM that includes several novel contributions: three main loops of DM, multiple repetition of loops, and possible returns to the starting point.*

Keywords: ERP, Enterprise System, Software Upgrade, Software Selection, ERP Upgrade, ERP Replacement.

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Introduction

Large companies have been using enterprise information systems (EIS), also known as Enterprise Resource Planning (ERP) systems, for decades. Besides, a growing number of small and medium-sized enterprises (SME) are implementing ERP systems to survive the increasingly fierce competitive struggle (Olson & Staley, 2012).

These systems are vital for companies; consequently, any related change or failure can pose a great risk, as there are a lot of failed ERP projects caused by different factors (Beatty & Williams, 2006). the scope of research in this field has been steadily growing (Feldman et al., 2015; Feldman et al., 2016; Fischer et al., 2017; Hidalgo et al., 2011; Huang & Yasuda, 2016; Hustad & Olsen, 2014; Khaled & Idrissi, 2011; Kilic et al., 2014; Lee & Chang, 2020; Lee & Myers, 2009; Mahmood et al., 2019; Ng, 2011; Ranjan et al., 2016; Romero & Vernadat, 2016; Vom Brocke et al., 2018). Among the main challenges are an improper business case from a strategic point of view (Mahmood et al., 2019) poor leadership, technical issues with software and infrastructure (Beatty & Williams, 2006; Huang & Yasuda, 2016; Mahmood et al., 2019), choice of a wrong ERP system or modules and, respectively, lack of organizational fit (Hung et al., 2013), cost underestimation, management of project and organizational change (Beatty & Williams, 2006; Hustad & Olsen, 2014; Mahmood et al., 2019), failing consultants, culture and management of enterprise change (Huang & Yasuda, 2016), ineffective implementation methodology, and rushed implementations (Huang & Yasuda, 2016). The list is not exhaustive. A required change in business architecture can also lead to a loss of competitive advantage.

Previously, research emphasis was on the early phases of the ERP lifecycle, e.g. the implementation (Aloini et al., 2007), or decision making (DM) (Bernroider & Koch, 2001; Hakim & Hakim, 2010; Stefanou, 2001), however now it has also been extended into maintenance and replacement phases, e.g. (Haddara & Elragal, 2000; Koch & Mitteregger, 2016; Law et al., 2010; Nah et al., 2001; Ng et al., 2003; Salmeron & Lopez, 2010), including tracking and optimizing benefits (Mathrani et al., 2009). In times of fast changes in markets and business technologies, companies not only need to change their business models, strategy or organizational structure, but also to maintain as well as constantly and simultaneously develop their information systems, especially their key systems like ERP.

An ERP system can and thus has to be upgraded to a newer version, which is the main activity in the maintenance phase (Nah et al., 2001). Sahin and Zahedi (2001, p.471) define a software system upgrade as "adding new functions or features to a software system, in addition to any maintenance and fault removal". Similarly, upgrade is a replacement of a current ERP version with a newer version or another ERP system from a different manufacturer (Ng, 2011). We adhere to these definitions assuming in general that ERP replacement falls into the latter definition of the ERP upgrade. The upgrades can be larger or smaller and are increasingly more often required by manufacturers (Olson & Zhao, 2006). Each such ERP upgrade is quite complex, so it is performed as an IT project with substantial resources and expenses. Numbers reported show that a single upgrade can cost up to 30% of the initial implementation cost (Ohlson, 2000).

There are many many reasons, why these projects may not be successful either. The reasons may include the problems with business vision, top support, project management, communication, user involvement, etc. (Olson & Zhao, 2006). These risks are thus similar, but not identical to implementation projects. A pure ERP implementation presumes a rather unconsolidated IT landscape for the existing business processes, while an existing ERP system assures a certain consistency of processes, data management, and IT integration. The latter simplifies the project, especially in the case of a true ERP replacement, and may even provide for a fall-back option in case of a project failure. On the other hand, the existing ERP might introduce certain limitations or risks for a system change, both technically in the context of data migration, and also with regard to the change necessary for employees and thus resistance. Therefore, the strategic risk of the company in relation to an ERP upgrade consists of the risk of an inappropriate ERP change decision and the risk of inadequate project planning and management. The risk of a wrong decision comes first, and determines the strategic future outcome and the scope of the project. The project risks are of smaller scale, mostly operational, and may turn out to be strategic only in the sense of ability to deliver the result in time and within the budget. Taking into consideration the frequency of upgrades and the related decisions, we believe that a thorough understanding of the ERP upgrade process should help to prevent unnecessary expenditures and decrease the number of ERP project failures (Olson & Zhao, 2006).

Unfortunately, time constraints for DM are tight because a relatively long delay of such a decision can cause considerable technical debt (Tom et al., 2013). Technical debt is a situation when a sound decision is postponed to a later time and is not bad on its own in the sense of future expenses. However, it makes the interrelations between business and IT requirements more complex with time. Thus, the same important decision about an ERP upgrade may be made too late and extraneous at some point of time in the future. There can be another situation and a different decision at stake. This new decision can be simpler and even cheaper, but can also be the other way round.

We argue that the process of ERP decision in the upgrade phase should address the main risks and shortcomings mentioned above. An ERP upgrade decision is “a decision made which results in the installed old ERP version (partly or as a whole) being replaced by a newer version either from the same or different vendor’s product” (Ng, 2011). ERP upgrade decisions are strategic decisions for an enterprise on whether, when and how to upgrade an existing ERP system. Beyond pure system engineering, the essence of ERP change is always bound to nontechnical changes, such as business process analysis and evolution, decisions on customization of ERP modules, business processes or both at the same time, etc. Specific methods applied in the DM model should be used to capture all necessary attributes of such alternative solutions, necessary decision criteria, and their dependencies. These methods are beyond the scope of the paper and can be found in the literature, e.g. Huang and Yasuda (2016); Ranjan et al. (2016); Fischer et al. (2017).

The knowledge about ERP upgrade DM is not comprehensive (Ng, 2011). The research goal of this paper thus focuses on the general DM process for such ERP upgrade decisions. This is exactly the process where all stakeholders participate and within which all possible options with relevant parameters have to be evaluated. Here, the representation of the DM context is in essence a model. The model parameters and variables should be consistently understood by stakeholders and comparable in time. Based on that, the technical debt (Tom et al., 2013) can be controlled. Ideally, the consequences of the decision should be analyzed because this expresses the effectiveness of the technical debt control.

Therefore, the research question is: What can a schematic and complete model of an effective and efficient ERP upgrade DM process look like? The process representation is built on the existing knowledge about ERP upgrade, but it also utilizes empirical input and a real-world case study, and addresses appropriate DM particularities related to consistent criteria aggregation for DM.

We contribute to the larger area of DM in the ERP context in this paper, through the design and evaluation of a full ERP upgrade DM process model. This has considerable practical implications as well as relevance. During the analysis of the DM process, we decomposed the usual steps in the ERP upgrade DM, and, after empirical verification, obtained three loops of repeated activity sequences. In effect, we found that the DM process extends beyond the traditionally assumed goal of the choice of action and can return to its very beginning. Eventually, the return condition can take effect during the implementation of the chosen project and thus, the ERP DM process proceeds along with the ERP upgrade project at least during its initial phases until the project stabilization. In the worst case, when the situation is very unstable and uncertain, the ERP DM process may continue to accompany the project, assisting with the necessary project changes until the end of the project. As the need for ERP upgrades of smaller scope is relatively frequent (Olson & Zhao, 2006), after the end of one ERP upgrade DM process another one usually begins. It turns out that ERP DM is a continuing part of the ERP lifecycle.

In the end, ERP DM under uncertainty devoted to ERP upgrade is a multi-criteria problem with multiple alternatives, or multi-attribute decision making (MADM). The analysis of the aggregated utility of the alternative options in the DM process is a non-trivial problem as it should be correct mathematically and easily applicable in practice. However, there are methods that seem to be a solution for the utility aggregation for ERP DM, e.g. multiplicative aggregation (Goman & Koch, 2018). Such methods should be integrated in the ERP DM process. The rest of the paper is organized as follows: We first present the research methodology, and then describe the related work. Further on, we proceed with a detailed discussion of the first design of the ERP upgrade DM process model, and present a case study used for the evaluation, together with the implications and the final model of the DM process. The paper closes with a discussion, conclusion, and directions for future research.

Related Background

ERP Systems and Decision Making

The ERP system is based on a set of integrated software modules and a common central database that enable an organization to integrate business processes in manufacturing, production, finance, accounting, sales, marketing, and human resources into a single software system. An ERP system provides for the use of the information by many different parts of the business, real-time planning, efficient management of resources in a fast-changing environment, effective re-engineering and automation of business processes, data sharing and access to updated information in real-time operation (Laudon & Laudon, 2018).

Existing today are many ERP selection frameworks. For example, Kazemi et al. (2014) have developed a multi-criteria DM methodology for ERP software system selection based on fuzzy multi-criteria decision-making methods. In application, the model is used only once after thoroughly selected model parameters. Khaled & Idrissi (2011) have proposed a methodology for the ERP selection for SMEs by constructing an induced decision model based on fuzzy measures and MACBETH scales with an iterative decision model. Mashari et al. (2008) have introduced an ERP selection framework built on a literature review and case study analysis. Wu et al. (2009) show a general model for the software system selection, including ERP selection. The framework is based on Simon's decision-making and has been adopted by many researchers. Onut & Efendigil (2010) have proposed a methodology with fuzzy AHP as a decision-making tool for the ERP software and vendor selection problem, and compared it to traditional AHP and fuzzy AHP approaches. Kilic et al. (2014) have suggested a hybrid methodology for ERP system selection based on fuzzy AHP and TOPSIS methods, considering an airline company. Hidalgo et al. (2011) have developed a methodology for the ERP software selection in the metal transformation sector based on the AHP method. Cebeci (2009) has developed a conceptual framework in the textile industry and proposed the fuzzy AHP-based methodology for selecting ERP systems.

All the above-mentioned state selection methodologies have one thing in common: a linear process of DM, and only some of them include a loop for adjusting and clarification of the model parameters. More or less sophisticated mathematical methods are used at the end to rank the ERP system and vendor alternatives. In addition, they focus on the ERP selection, i.e. the first phase in a life cycle model, not the upgrade.

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A software life cycle is defined as the "evolution of a system, product, service, project or other human-made entity from conception through retirement" (ISO/IEC/IEEE, 2017). As any software, ERP systems are developed, sold or acquired (and possibly customized), implemented, and undergo a number of changes and transformations during operation before their eventual disposal. Each phase of the ERP lifecycle includes decisions, and "The purpose of the Decision Management process is to provide a structured analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for a decision at any point in the life cycle and select the most beneficial course of action." (ISO/IEC/IEEE, 2017).

An ERP lifecycle can be represented as a number of phases (Stefanou, 2001). For instance, Markus and Tanis (2000) define four phases in an ERP system lifecycle, while Esteves & Pastor (2001) define six ones. The models are compared in Table 1. Both have the phases that include all maintenance, support, and upgrade activities – the "onward and upward phase" in the former paper, and the phases of maintenance and evolution in the latter paper. Upgrades take place during these phases, and can be as challenging, complex, and problematic as the initial ERP implementation (Otieno, 2010). Each phase can be divided into smaller ones, e.g. Ng et al. (2003) have developed an ERP maintenance model, which consists of three major phases: maintenance preparation, maintenance procedure and software upgrade. Upgrades can require large technological and organizational changes in the company as well (Bernroider & Koch, 2003). These changes should be carefully planned and performed in order to retain the competitive business advantage of the existing ERP solution. Decision-making is an integral part of all phases, ranging from the choice of the adoption system to decisions in the implementation phase, and further the maintenance that is the focus of this paper. Naturally, some of the decisions are of smaller scope and impact, e.g. the particular implementation or process design decisions, while others, especially system selection, are of higher impact.

Table 1 - Comparison of lifecycles

Markus & Tanis (2000)	Esteves & Pastor (2001)
The chartering phase	Adoption decision phase
	Acquisition phase
The project phase	Implementation phase
The shakedown phase	
The onward and upward phase	Use and maintenance phase
	Evolution phase
	Retirement phase

Conceptual roots of the ERP DM process can be traced to the manager's DM process from Simon (1997) and Huber (1980). They considered mapping of the DM process onto problem solving. DM therefore includes three stages: intelligence, design and choice. Problem solving added another two stages: implementation and monitoring. We will follow the cited stages in building our ERP DM model.

ERP Upgrades

In the operation and maintenance phase, changes to the existing ERP system are performed. Abran and Nguyenkim (1993) note that major upgrades of software systems should be treated as system development. We have arrived at the same conclusion for ERP systems because of the complexity of the change and its performance as a project. This project is complex and connected to corporate DM. Little relevant literature exists that clearly defines ERP upgrades as part of maintenance (Barth & Koch, 2019).

An overview of ERP upgrade types in the life cycle, upgrade drivers, and factors can be found in Feldman et al. (2016); Feldman et al. (2013). An upgrade action involves new programs and constitutes an overhaul of the system. We understand an ERP upgrade as a major change of the already installed ERP system that includes implementation of new versions of application software with new functions. At the same time, the upgrade of the existing functions enables the usage of new technologies and business strategies.

Basically, there are two categories of upgrades: minor (the same version) and major (a new version) upgrade (Ng, 2001). ERP upgrade decisions at a minimum involve deciding on the amount of changes (especially custom modifications) to implement and the time to upgrade the ERP system with a newer version. According to Ng (2011), a system-to-system upgrade takes place when current version of the installed ES does not meet the company needs and is replaced with another ERP system from the same or a different vendor. During the version-to-version upgrade, however, the same ERP system is upgraded to a newer version released by its manufacturer.

An average organization has to perform an ERP upgrade every three years (Olson & Zhao, 2006), each time with expenses between 25-33% of the initial ERP implementation costs. Thus, the upgrade costs can exceed the implementation costs several times during the ERP lifecycle. Lack of specific guidelines for the ERP upgrade planning and performance has already been identified as a research gap before (Ng et al., 2003). Should a gap exist in the ERP upgrade expertise at an enterprise, the importance of an efficient ERP DM process increases considerably. This is because a systematic DM control sequence should enable the minimization of the strategic risk of an improper ERP upgrade choice. This is related not only to changes in IT infrastructure, software and business processes, but also to the choice of a project structure, partnerships, maintenance and business management in the future after the upgrade.

ERP vendors generally reserve a finite time period for maintenance for each version of their ERP. There can be possibilities to wait and upgrade to the newest version by skipping several versions, accept limited support service, or do completely without it.

A lot of criteria and factors have an effect on the ERP upgrade DM. Most of them are not about one-time action only, but rather influence, respectively constrain, future decisions, change options, costs and benefits. Modifications of the ERP functionality may be needed for an organization's existing (or required) business processes and they may affect the complexity and costs of the subsequent maintenance. Additional testing and data transformations may be required on every small change. However, business processes may also be adapted to the functional possibilities of the ERP more easily and with the effect of easier achieved benefits. Other expenses should also be analyzed and addressed, e.g. user training, extra consultants or analysts, project delay and ERP system breaks or data integrity issues during operations are also possible.

The need for an ERP upgrade is twofold: it has internal and external drivers (Beatty & Williams, 2006). On the one hand, an enterprise realizes the need for ERP improvement for business benefits. On the other hand, vendors urge organizations to upgrade their systems because

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ERP systems are constantly evolving due to marketing needs – for the ERP manufacturers to remain competitive and be able to provide good support for a reasonable number of versions.

Among the goals of ERP upgrade, there are taking advantage of new technologies (Dempsey et al., 2013), preserving business competitiveness (Otieno, 2010) and cost reduction (Ng, 2011). Vendors are interested in customer lock-in and reduction of support costs through a smaller number of installed ERP versions. Cost and time frames of ERP upgrade are the most important parameters of the action. A good DM process should ensure a trade-off between these parameters as well as smooth fulfilment of the upgrade and individual objectives.

An ERP upgrade decision is about a partial or whole replacement with a newer version or a product from a different vendor (Ng, 2011). The ERP replacement (retirement) phase of the ERP lifecycle is the stage when a certain ERP system is not simply upgraded to the newest possible version of the same system, but is replaced completely by another ERP system (Haddara & Zach, 2011). The latter is usually more complex and is in its essence a new ERP selection and implementation. We adhere to the conclusion of Haddara and Elragal (2000); Haddara and Zach, (2011); Haddara and Elragal (2011) that the ERP retirement phase has not received sufficient attention in studies.

An ERP upgrade can take place when new competitive ERP technologies appear, or the company dramatically changes, so that the current ERP system becomes inadequate to the changed business requirements and existing processes, or as shown by Haddara and Elragal (2000), the retirement can happen before full implementation and realization of expected benefits due to a wrong system selection. Similar factors that force companies to replace their current ERP system are: complex and costly supportability of obsolete systems prevents new developments and cannot assure the satisfaction of business requirements; tremendously growing maintenance costs may not improve the deteriorating functionality and reliability; the old system or software architecture, outdated technology cannot provide for further development (ERP evolution); new solutions and technologies appear in the market that promise business opportunities and simpler maintenance; corporate merger, etc.

Methodology

For this research, a design science approach has been adopted, as the main goal of the study is to develop a process model to address a business problem of the ERP change, respectively upgrade. Design science as a research framework for information systems research is concerned with building and evaluating artifacts, including software, conceptualizations, or mathematical models (Hevner, 2007). In case of the research, the artifact is the process model for the ERP upgrade DM. Hevner et al. (2004) also highlight the need for structured guidelines regarding its conduction, and provide seven guidelines for a practical application of design science research, including problem relevance and research contribution as well as rigor. Hevner (2007) clearly distinguishes three design science research cycles: relevance, rigor and design. Peffers et al. (2007) have developed a six-step process framework for the application of the design science research method.

The research process of this paper draws on design science and these guidelines. We first established the problem and its relevance by focusing on the literature on the ERP system upgrades, and the related DM processes. The literature search spanned most relevant online databases (Google Scholar, Scopus, Web of Science) and used the main search string combinations of ERP with different versions including enterprise systems, enterprise resource planning etc., combined with variations on upgrade, replacement and/or DM. Inclusion criteria were the presence of a decision process, decision model, or a literature review related to the modern ERP upgrade problems. We studied the abstract and full text of the papers returned by search engines as relevant and decided on their importance to our research objective. The principal papers that we found are given in Table 2. Based on the elements from literature, we developed the first version of the process model design. The design is thus grounded both in the problem analysis, as well as prior work and theory.

Having designed the initial DM mode, we performed a first evaluation using a real-world case study and improved the process model. A case study was chosen to be able to both evaluate the artifact through different lenses, and also because the context is highly complex and involves both different stakeholders as well as activities over an extended period of time, and relatively complex decisions and cognitive processes. A more qualitative approach was thus deemed better suited than a quantitative method. Through this overall process we both addressed the design and the rigor cycle of Hevner (2007), and arrived at the final artifact of the respective DM process model that constitutes the contribution of this paper. According to Gregor and Hevner (2013), the contribution of this paper can be classified as exaptation, as the application domain of the ERP upgrade DM is still in low maturity, and the framework extends previously known solutions.

Initial ERP Decision Process Model

Most DM models in literature refer to a one-time IT system acquisition problem or the ERP initial selection problem. Table 3 provides an overview of prior ERP DM models. For example, Karsak and Özogul (2009) represented the ERP selection process and decision model Based on fuzzy linear regression. Ng (2001) developed a mathematical model for DM in case several possibilities for ERP enhancements exist, based on financial cost-benefit analysis. Cebeci (2009) showed ERP DM flows for strategic management and decision phases of ERP selection that contain cycles for choice of simple parameters, and for the acceptability of the results of analysis before the final decision. All of these models assume one-time decisions. However, the reviewed literature provides for generic DM processes. As the main underlying model, we chose the IT assessment framework (PITAF) (Bernroider et al., 2013) which can be considered a summary of the IT DM process (see Figure 1). The PITAF framework already is set up for any information system evaluation and choice, a DM problem with multiple criteria (dimensions), ranking of alternatives, and acknowledges the need for the multidimensional aggregation of the criteria combined with DM's preferences. Due to these characteristics, we found the PITAF framework (Bernroider et al., 2013) to be the most comprehensive model and chose it as the basis of our DM model development. The ERP upgrade DM similarly needs to consider several dimensions in the evaluation and fits the general category of information systems evaluation and choice.

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Table 2 - Summary of identified key papers on ERP decision-making and process

Authors	Year	Title
Bernroider and Koch	2003	ERP system acquisition: A process model and results from an Austrian survey
Bernroider et al.	2013	A comprehensive framework approach using content, context, process views to combine methods from operations Research for IT assessments
Cebeci	2009	Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard
Feldman et al.	2017	A systematic approach for enterprise systems upgrade decision-making: Outlining the decision processes
Hidalgo et al.	2011	ERP software selection processes: A case study in the metal transformation sector
Karsak and Özogul	2009	An integrated decision making approach for ERP system selection
Kazemi et al.	2014	Selecting an ERP system using multi-criteria decision making method: A goal programming and fuzzy approach
Khaled and Idrissi	2011	A semi-structured methodology for ERP system selection based on MACBETH and Choquet integral applied to small and medium sized enterprises
Kilic et al.	2014	Development of a hybrid methodology for ERP system selection: The case of Turkish Airlines
Mashari et al.	2008	The Enterprise Resource Planning (ERP) selection process: Case analysis and proposed framework
Ng	2001	A decision framework for enterprise resource planning maintenance and upgrade: A client perspective
Ng et al.	2003	An ERP maintenance model
Onut and Efendigil	2010	A theoretical model design for ERP software selection process under the constraints of cost and quality: A fuzzy approach
Wu et al.	2009	Using multiple variables decision-making analysis for ERP selection
Zeppetella et al.	2016	A decision framework for upgrading ERP systems

Table 3 - ERP DM models summary

Paper	Applying area	Specific features of DM model
Cebeci (2009)	Textile industry	A loop for analysis results check before decision
Karsak and Özogul (2009)	General ERP DM selection model	The DM model includes a loop
Ng (2001)	General ERP DM maintenance and upgrade	A cost-benefit model for ERP maintenance model
Bernroider et al. (2013)	Large public sector organization	PITAF framework for ERP DM with explicit dimensional aggregation step and ranking of alternatives
Bernroider and Koch (2003)	Small and Medium-sized Enterprises (SMEs)	Feedback loops within phases of the ERP lifecycle

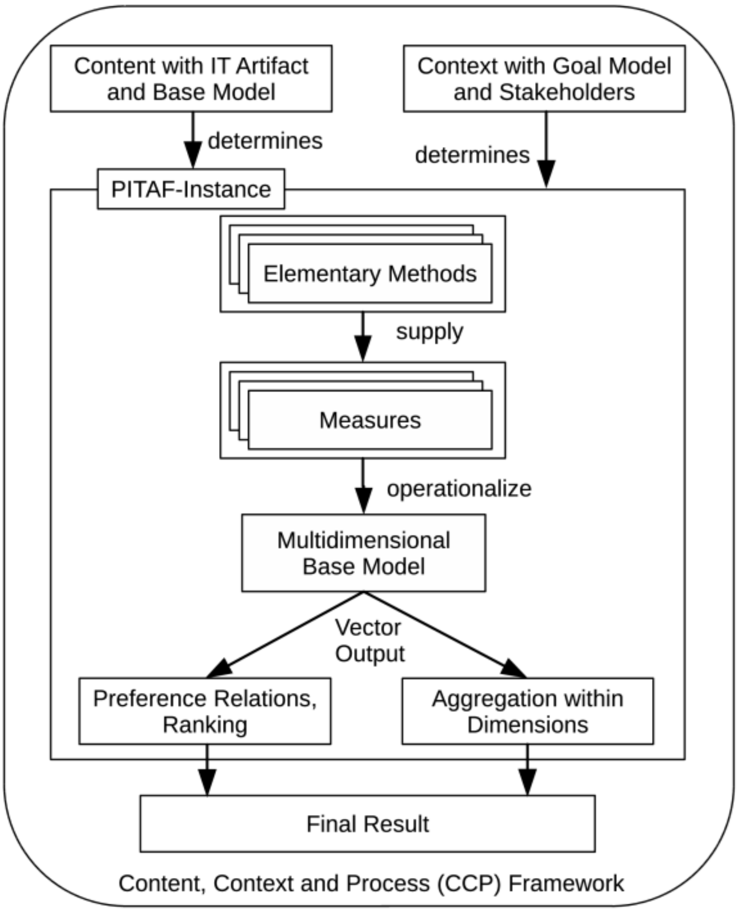

Figure 1 - Key elements of PITAF framework (redrawn after Bernroider et al., (2013)).

We also found that Bernroider and Koch (2003) focused on the ERP acquisition process in the context of the ERP lifecycle. They considered an ERP as decomposed into packages and recognized an information feedback loop in the ERP lifecycle model between "Adoption decision" and "Acquisition" phases. We can generalize this to the ERP upgrade case because there are a lot of similar activities: requirements and specific conditions are defined in "Adoption decision", and analysis of packages and related tasks are performed in the "Acquisition" phase. Our paper deals with both of these phases because upgrade (especially with the transition to a system from another manufacturer) includes the adoption decision and all activities from the two referred phases. These two phases therefore also form a basis for

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the more detailed ERP DM process developed in this paper. Thus, the possibility of several iterations in the ERP DM was already recognized in this base model. The loops in this model represent refinement of the decision criteria and determination of alternative solutions, but there is just a single step of the system choice that we will further elaborate on.

Unfortunately, beyond the assumption of one-fold decision iteration and a focus on the initial selection, the models do not generally imply that aggregation of criteria of each alternative is done in a form of a mathematical model, but rather application of a simple scored technique or using a decision support method (e.g. AHP, ELECTRE, etc.) (Cebeci, 2009; Feldman et al., 2017; Hidalgo et al., 2011; Kazemi et al., 2014; Khaled & Idrissi, 2011; Kilic et al., 2014; Mashari et al., 2008; Onut & Efendigil, 2010; Wu et al., 2009; Zeppetella et al., 2016). Moreover, even if the modeling is explicitly included in the ERP decision model, it is still a single activity after the necessary information has been collected, e.g. (Karsak & Özogul, 2009). We presume that a decision may not be made based on processing of the collected information, i.e. the best alternative is not evident in the first evaluation. Thus, the possibility of clarification, refinement or update of the information is missing in the models. We explicitly allow for this possibility.

Anecdotal evidence from practice confirms that the models applied are usually rough, and often employ many expert estimations expressed in the ordinal scale or scores. It is not easy for decision makers to choose an alternative. But the set of possible alternatives is usually finite and known, and a choice must be made. In these circumstances, we suggest adding the missing option of the improvement of information on alternatives and repetition of the choice step.

Summarizing the review, to produce the initial model for our research, we built on the initial steps from Karsak and Özogul (2009); Bernroider and Koch (2003) processes with slight modifications. We consider the straight flow of preparatory activities as the preparation of the set of alternatives, system requirements, and criteria, but the choice is represented by a number of possibly repeated activities (a loop). Loops in the model in Bernroider and Koch (2003) belong exactly to the preparatory activities. Moreover, we show in our decision model that decision makers deal with a precise mathematical model where dependencies between requirements, criteria and alternatives' parameters are given. Therefore, we added two specialized steps from the process in Bernroider and Koch (2003). At first, we expanded the step "Evaluation and Comparison of Alternatives" from Bernroider and Koch (2003) with the stress on the application of a formal mathematical model (e.g. an economic model, as in (Ng, 2001) in the DM process). And second, taking the idea of dimensional criteria aggregation and explicit ranking of alternatives (Bernroider et al., 2013) at the step of the decision (choice), we elaborated the step "Choice" from Bernroider and Koch (2003) with a loop of iterative evaluation of the modelled alternative's criteria and factors, model improvement, and the clarification of the attribute values.

This led us to suggesting the following decision process model for the ERP upgrade (see Figure 2). This model assumes a one-time decision as well. The model contains a cycle of decision improvement that was not clearly indicated in other models. This cycle can be repeated several times within the available budget constraints, i.e. while the value of additional information can allow it and sensitivity analysis shows a direction to improve the decision via additional experiments. Analysis for the choice of the most suitable alternative is not performed only once as in a single isolated scenario, but rather can be repeated provided that there are uncertainties that prevent the reliable final ranking of the alternatives for the decision to be made.

In the first step "Understand client's objective", the purposes of the ERP change should be clarified. This step is required for two reasons. Firstly, while there can be a formal statement with respective goals, the semantics can be misunderstood by an external stakeholder person who is not part to the everyday communication within the organization and thus lacks the context, so some of the main objectives may be misinterpreted by some of the process participants. Secondly, the purposes can be detailed and extended following a discussion during this stage. This work would usually be performed in the form of one or several interviews or workshops where all stakeholders of an ERP change project can discuss all relevant questions for the business case, e.g. reasons for the change, objectives and metrics, resources and constraints. The outcome of the stage is an updated set of the goal statements.

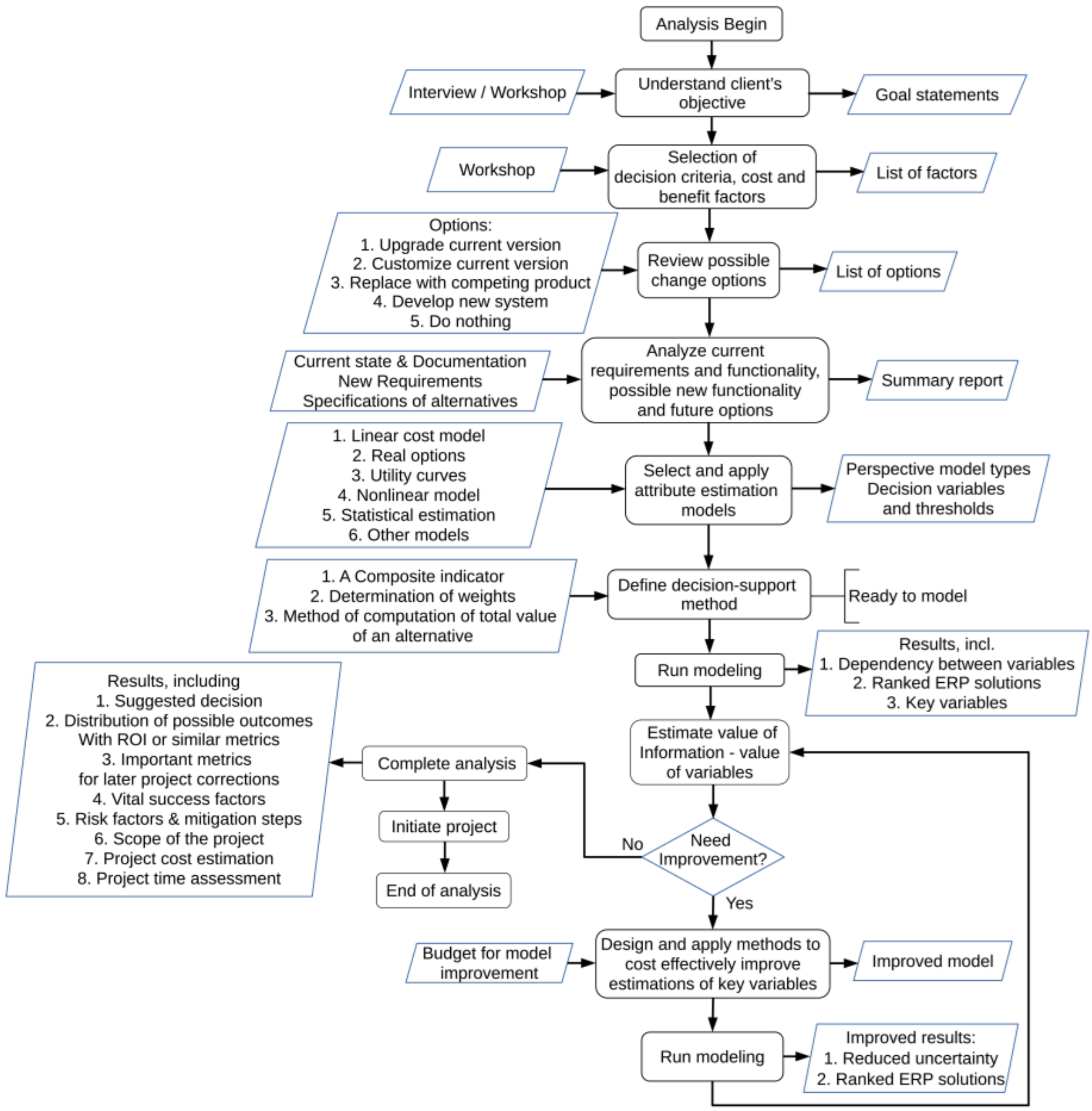

Figure 2 - Initial ERP upgrade decision process

The second step, "Selection of decision criteria, cost and benefit factors", is another set of workshops where a structure of the decision matrix is developed. Attributes of alternatives and decision criteria for them as well as criteria dependencies should be carefully chosen and approved by decision makers. Generally, attributes like different cost aspects, functionality or market position of the vendor are included here. For instance, Barth and Koch (2019) and Ratkevičius et al. (2012) provide some empirically derived lists of attributes and criteria. The

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outcome is a prototype of the decision matrix with important factors (attributes and their optimization criteria like maximization or minimization) and operational units of their measurement (e.g. monetary units, time or number of people).

In the third step, "Review possible change options", a review of possible solutions should be performed. These can be high-level descriptions of the options. Among the choices, there may be an ERP upgrade, further customization of an existing system, replacing with a different product (e.g. from another vendor), development of a new system, etc. The outcome is the list of options with relevant details.

Step four, "Analyze current requirements and functionality, possible new functionality and future options" comprises the following tasks:

1. Deep technical and economic analysis of the ERP change options identified on the previous step.
2. Profound study of the current ERP system, IT infrastructure and business processes.
3. Identification of constraints and risks of the planned projects.

All the tasks should be well documented. The output is a report that contains all gathered descriptive information about the current ERP and IT environment, requirement specifications for the ERP change and detailed specifications for every alternative option.

During step 5, "Select and apply attribute estimation models", an objective function, constraints, laws of variable dependencies and their contribution to the objective function should be defined. Formulae to compute the estimates of attributes where necessary are defined in this step as well. The model is represented mathematically using appropriate theoretical models and notations like a decision matrix and can usually be expressed as an optimization problem. This is primarily a financial concern, nevertheless a lot of analysis is needed for the determination and verification of dependencies and parameters. Experts may be extensively used to obtain the required estimations of variable values, coefficients and thresholds. The model also includes textual information that defines the background principles and variables, thresholds and other relevant information for model comprehension by other actors.

Within step 6, "Define decision-support method", a method for DM support is defined, i.e. how to aggregate the performance of every option and compare the options. The step includes evaluation of the objective function, criteria and constraints. The method should enable ranking of the alternative options based on the information from the previous step.

It is important to note that the decision criteria chosen in step 2, the variables from step 5, and the decision-support method from step 6 must maintain dimensional integrity and be coherent with the laws of mathematics and logic (Goman & Koch, 2018). In managerial DM, the MADM problem requires responsibility for the proper choice. The decision usually employs a model where the criteria (possibly dependent) define the way how the attributes create the alternatives' utility, attributes measure factors and objectives (as dimensions of the problem), and there should be an objective function that derives the total value of each alternative. The choice must be performed on the aggregated total value that enables ranking of the alternatives from the worst to the best. The objective function and the selected decision-support method must enable consistent aggregation of data from multiple *noncomparable* dimensions (properties) of the alternative.

One of the feasible solutions here is the application of a composite indicator as the objective function (Goman & Koch, 2018). This indicator should be based on the principles of multiplication, and the attributes must be expressed in real numbers of the ratio type in the natural scale of the attributes. This enables the required consistency of data representation and processing, and assures validity of the aggregation outcome. We assumed the aforementioned requirement in the study and adhered to it in the case study. Assuming maximization criteria for all attributes *j*, the expression for the composite indicator (CI) for an alternative *i* can be computed as follows (Goman & Koch, 2018).:

$$CI_i = \frac{\prod_{j \in S^+} b_{ij}^{w_j}}{\prod_{j \in S^-} b_{ij}^{w_j}}; \quad b_{ij} > 0; \quad w_j > 0,$$

where b_{ij} are attribute values of alternatives,

w_j are weights,

S^+ is a set of attributes with only positive meaning and values, and maximization criteria,

S^- is a set of attributes with only negative meaning and values. They initially have minimization criteria, and require certain preprocessing to change the criteria to maximization ones, and

all variables in the expression have ratio scales.

Step 7, "Run modeling", is finalizing the model and computing it respectively for the first time. This includes model representation in a specialized modelling software or in a spreadsheet software and estimation of any kind of variables that were not finished in the previous steps. The outcome is a set of estimated values of parameters defined in step 2 along with additional information like sensitivity analysis. The main result is a ranked order of the change options according to their aggregated value to decision makers obtained with the decision-support method. If the composite indicator as proposed above is used, the result for each alternative determines the ranking.

In the next, 8th step, "Estimate expected value of additional information – value of variables", the difference, respectively the distance between the best and the second best options, is determined through a simple comparison. This determines the maximum amount that an organization should be willing to pay for refining the details of the options and reduction of uncertainty of their parameters. Hubbard (2020, ch. 12) provides details on the value of additional information. A fraction of the expected value of additional information can be regarded as a budget for the additional research for the next step, on condition that the difference in ranking seems not sufficiently persuasive to decision makers, or there are uncertainties in the model or estimates, or sensitivity analysis shows that the best solution is unstable.

All the relevant information should be ready before the decision in step 9, "Need improvement?" where the decision maker evaluates the ranking of alternative solutions of the ERP upgrade options. The decision maker should consider the modelling results and decide on whether the result is acceptable and a single solution can be safely chosen. Otherwise, he can demand model improvements and should approve the budget for it as a fraction of the value of additional information from step 8.

The model can be improved in a cycle many times as long as the decision maker finds the uncertainty substantial and there are enough resources for additional study and modelling. Within the cycle, the next steps, "Design and apply methods...", cost-effective methods for variable estimation or dependency improvement should be chosen. This means that substantial parts of the model or only certain parameters may need changes. After the model update, the modelling is performed again in the "Run modelling" step, and new results are produced. The results are considered by the decision makers again, in step 9, "Need

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improvement?", and the cycle of the model improvement and modelling is repeated on condition that there is a need and resources for further analysis.

Once the result of the modelling is accepted, a report is prepared, which can include such items as the suggested decision, a distribution of possible outcomes of ROI or similar metrics, key metrics for project planning and control, description of vital success factors, risk factors and mitigation techniques, project scope, project cost and time estimations and so on. If the project plan has been prepared during the previous stage, the project can be initiated in the next step.

Model Case Study

Setting

For evaluating the preliminary process design in Figure 2, a case study with a large automotive company in a late stage of their ERP change initiative was used. This was an opportunity to compare the designed process empirically to a case of the real-world ERP DM. Based on the additional information and insights, the DM ERP model was updated as described below.

The focal organization is an automotive company that was established in the 19th century. It has about 3000 employees, and has average revenue of close to $1 billion per year. The company is one of the largest manufacturers of its specialized market segment. There are 16 production facilities on 3 continents. It has sales and service subsidiaries in more than 100 countries, and multiple service partners all over the world.

The company runs an ERP system with in-house developed components that is more than 20 years old. It consists of a self-developed production planning system software, financial and accounting ERP subsystems, and a CRM subsystem from outside vendors. The system overall thus relies on a number of piece-meal third party applications, database management software, system software, and infrastructure facilities. The decision to change the old system was due to the anticipation of an inability to efficiently maintain and further evolve it.

The ERP change initiative was launched in 2015, but the project was suspended in 2017 when the implementation partner was re-evaluated. The first step of the project was finished in 2019 including nine months of analysis and DM on the new ERP. The ERP software was supposed to be upgraded first in the company's headquarters, and then rolled out to other locations. This model will also be applied for every additional module which will later be integrated into the ERP system. A re-evaluation of the integration partner is necessary due to the fact that there are not many partners with expert know-how on all ERP modules.

Data Collection

For getting a full picture of the ERP decision-making process applied, we used several information sources that were made available by the organization. The head of IT was the main sponsor and support for data collection. As the first step, we collected data from the project files made available and reconstructed the course of the DM process in the ERP change initiative, including all steps, employed decision models and their parameters. Namely, but not limited to, the following documents were made available, were judged as relevant and thus analysed: meeting minutes and vendor presentations, ERP requirement specifications and business process descriptions, requests for proposals and response analysis files, technology and vendor evaluation reports and models. The models and also some further analyses were provided in the form of spreadsheets.

Based on this document analysis, the conceptual ERP DM process (Figure 2) was compared to the constructed empirical process. After that, structured interviews were performed with the persons involved in the ERP DM and related projects: This included the project manager and CIO from the focal company, and a project manager and CEO from a consultant company that had helped during later stages of the process, and were also involved in other ERP projects beyond the focal company. The meetings were either transcribed or recorded, or, in one instance, notes were taken during the meetings. Overall, about 5 hours of three different interviews were conducted. The first interview was dedicated to the introductory presentation of the initial DM process and familiarization with the ERP upgrade project at the company. Persons from both the automotive company and a consultant company were present. The second interview was on the intermediate version of the DM model and its completeness with the consultant company alone, including clearing of some more detailed questions on the past projects. The last meeting was devoted to the final evaluation of the improved DM process and conclusions, and both companies participated. All meetings were performed in person, and both individual meetings and also a joint meeting were conducted. In the interview meetings, the current practice and experiences were considered, and especially the specificities of the DM process at the company were discussed. This included the reasons behind both process choices and also ERP as well as the vendor evaluation criteria and choices. Questions also focused on the results of the DM process. Finally, the proposed DM model was presented and discussed, especially whether the process that actually took place fits the model, and how an implementation of the new process is evaluated. This process assured that several data sources were used for all aspects of the process, thus providing triangulation.

For instance, the following aspects regarding the proposed ERP DM model were considered in the interviews:

1. Application of a formal DM process.
2. Degree of compliance of the proposed model to real corporate DM.
3. Applicability of the initial and revised models at the company.
4. Adjustability of the method to the needs of practitioners.
5. Revelation of new knowledge about DM from the revised model.
6. Usability topics and incentive to implement the model in future DM.

Analysis

In this section we will explain the execution of the actual ERP DM process as it is shown in Figure 3. The ERP change is a part of the overall IT transformation of the company. The ERP change process in the case study consisted of the following steps: definition of the system landscape, ERP requirements development, ERP requests for proposal (RFP) evaluation, ERP system decision, project budgeting, vendor selection, pilot project with the vendor, and implementation of the new ERP. The only possible ERP change option considered in depth is an upgrade that replaces the current ERP with a new ERP solution that satisfies all the requirements, including the legal ones, in several countries of presence and is available in different language versions. The goals of the change included:

1. Replacement of the old isolated core ERP system solution and related systems.
2. Search for integrated solutions that can integrate all global business processes.

3. Meeting international requirements for the company's growth.

4. Increasing the efficiency of daily work through a consistent and easy-to-use solution, evading multiple redundant data collection and processing.

5. Assuring the necessary licenses, maintenance contracts and support services within the budget.

Initially, a list of factors (attributes) and criteria was defined. They can be divided into several categories: functionality, scale of international activity, references, economic situation of the ERP manufacturer, and functionality. A linear decision model was used in the analysis that averaged the ratio and the nominal, and ordinal (0-4) scales of the estimated values of the decision variables. Maximization criteria were assumed for all the decision variables.

The first iteration of the decision process aimed at deriving a number of the best suited ERP solutions, i.e. narrowing down the field of possible technology providers. The number of the initial ERP system options was 10. RFP and detailed specifications were prepared. Obligatory ERP modules were finance, sales, purchasing, warehouse, material management, production, quality, after sales, and engineering. Three ERP solutions were chosen into a short list at the end of the first iteration of loop 1.

The second iteration of loop 1 followed. The objective was to choose the IT implementation partners of the respective ERP manufacturers for prospective projects. The list of factors included detailed vendor's references, descriptions of company profiles, economic performance, the firm's expertise in roll-outs and project team experience, significance for long-term partnership, support capabilities, representation in different regions, etc. Seven implementers participated in the analysis for the three candidate ERP systems chosen in the previous iteration (one of the solutions was to be implemented and thus represented by only the ERP vendor firm itself). A need for another loop 1 iteration was acknowledged for the improvement of information for DM at the end of the iteration because a need was identified for a number of new specific decision criteria for the implementation partners.

The goals for the third iteration were a detailed cost and benefit comparison, collection and analysis of further references for the maximum of two implementation partners for each ERP system to choose from. The updated criteria included detailed partner capabilities, how well the ERP systems satisfy the requirements and what kind of customization may be required, ERP ease of use and scalability. Additionally, evaluation of user experience of ERP solutions through business cases, cost of licenses and support, satisfaction with vendors and implementation project, and vendor's financial performance were studied. Five implementation partners participated in the analysis for the three prospective ERP systems, but two of those for one of the ERP solutions united to implement and support it together. Two best ERP solutions were identified with their corresponding implementation partners. A need for a detailed final comparison of the two best ERP solutions together with their respective partners was identified at the end of the iteration.

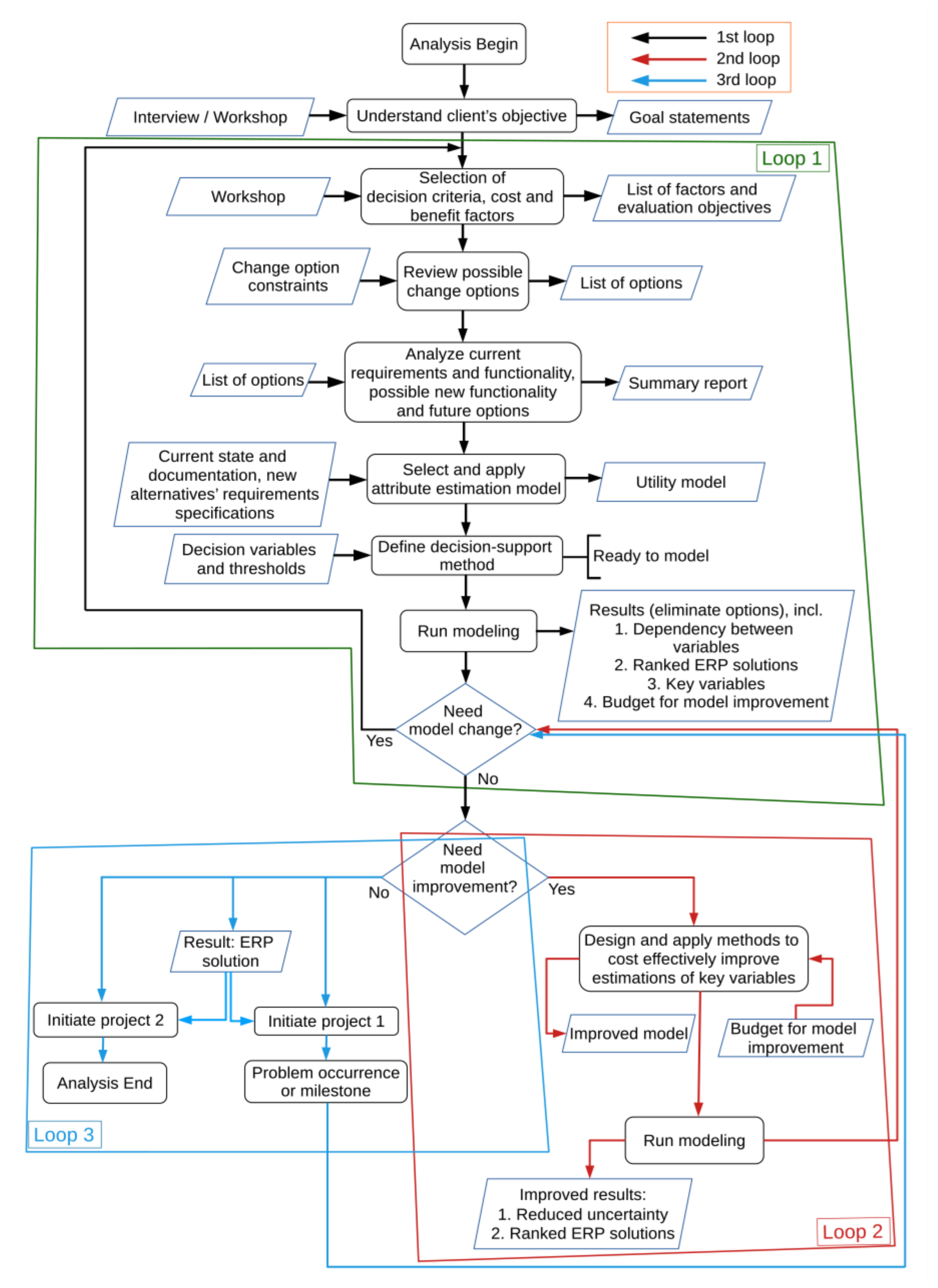

Figure 3 - Revised ERP DM process

The objectives for the fourth iteration of analysis were the license cost and risks in the ongoing service contract. This analysis was devoted to specific details of the two best ERP solutions identified. The analysis was performed in loop 2. Additional information was collected and analyzed, negotiations on price and terms of support were conducted. As a result, one of the alternative ERP systems and an implementation partner for the following project were chosen.

A pilot implementation project was started with the winner system and implementation partner. This was iteration 5 of the process in loop 3 where prototyping was performed during which an inconsistency in a critical system technology was found. Due to the fact, the project was terminated, the analysis was resumed in another iteration of loop 1.

The goals for the sixth iteration were the identification of a preferred technology solution from the two remaining ERP solutions and their partners obtained in iteration 3. Detailed cost and benefit comparison, time of project implementation, infrastructure compatibility, and availability of an international service network were re-evaluated given the results of the pilot project on the previous iteration. A new best ERP system was chosen. However, another comparison for the remaining two partners for the ERP implementation was required. This was done on the seventh iteration in loop 2, where additional information was acquired for DM. After the partner had been chosen, the implementation project was started in loop 3.

Revised Process Model

The ERP upgrade decision process model in Figure 2 was evaluated using an ERP change case study with a large automotive company. The case study was analyzed in detail in the previous section. According to our observations, the real DM process does not support a one-time decision, but instead is a repeated process. The process supports decisions of ERP evolution during the whole ERP lifecycle. Additionally, it has more than one cycle. Therefore, the initial model of the ERP upgrade decision process in Figure 2 was enhanced.

The revised ERP DM process is shown in Figure 3. This process now shows three loops that may be repeated. The main change resulting from this case study evaluation is the possibility to return to the early stages of analysis – "selection of decision criteria, and relevant factors" in loop 1. In our case study, the analysis went this way four times. There was an iterative elimination of alternatives and improvement of the solution. Some iterations of loop 1 are predefined because sequential processing of criteria may be needed. For instance, one iteration to choose the best suitable ERP solutions, and another one for identification of the best implementation partners can be obligatory as it was in our case study. Revision of alternatives at the beginning of loop 1 and subsequent elimination of them at the end of the loop is performed in this case. Thus, multiple repetition of all loops with optional exclusion of some steps is possible.

The larger loop 1 works with general model settings and changes in the decision structure. The smaller loop 2 is for clarification of particular model parameters of DM's interest that can be hard to measure, needed only once or require unique tools. Usually, the analysis is performed in loop 1. If special uncertainty in the model parameters or a particular difficulty in their estimation emerge, these issues are resolved in loop 2. Loop 3 represents prototyping or project phase when a pilot or real ERP change project begins. This loop has also been added due to the evaluation phase via case study, but is believed to be applicable and relevant to many organizations.

The decision model is being constantly built or improved in loop 1 so that there may be several repetitions of loop 1. The need for an (additional) model change is reflected in the "Need model change?" decision element. The return to this decision point can happen after several runs of loop 1 due to sequential model development (as shown in the case study in the previous section). A conditional transition here can also mean acknowledgement of inefficiency of the current model, change of criteria, change of risk statement or management goals, etc.

Therefore, one can transition to this point after problems identified in loop 2 or even in loop 3 (as was shown in our case study).

If the results of the analysis with the current model leave uncertainty for the decision maker in choosing a solution, the necessity of the existing model refinement is provided for in the “Need model improvement?” element. This transition generally represents the need to improve details, values, add additional variables, or other minor changes to the current model. The alternative transitions are as follows:

1. Continuation of the model analysis in loop 1 (see the black exit “Yes” from the element “Need model change?” in Figure 3). An ERP DM process would normally mean that several iterations of improvement of parameters of the remaining alternatives are required. Iterative narrowing of alternatives is performed during loop 1 repetition (alternatives are compared according to different objectives). An example of this was given in the subsection “Analysis” above. If such iterative comparison is employed, repetition of loop 1 is predefined by the given DM process until all steps with their objectives are completed, and the black exit “No” in Figure 3 from the “Need model change?” element can be used.

2. Parameter clarification in loop 2 (see the red exit “Yes” from the element “Need model improvement?” in Figure 3). The result is evaluated also against the model consistency at the decision node “Need model change?”.

3. Initiation of a project to upgrade the ERP system in loop 3 (see blue exit “No” from the element “Need model improvement?” in Figure 3), if it is possible to make the decision based on the current state analysis.

4. Should any problem happen, or the solution turned into an unacceptable one in loop 3, the analysis should return to the node “Need model change?”, and it should be decided whether the analysis should continue with model change in loop 1 or model improvement in loop 2. In particular, the situation in the case study where the pilot project was terminated represents this possibility because the chosen solution had become invalid. So, the analysis of the two remaining alternatives had to be repeated due to internal regulations.

Among the identified important improvements to the initial ERP DM process, there are the following important DM process properties:

1. Only the possibility to migrate to another ERP system can exist or be considered, i.e. the list of the ERP change options can only contain the ERP systems to replace the current one.

2. The main loop 1 serves for the main DM steps, e.g. determination of the feasible IT systems, evaluation of implementation partners and determination of candidates for deep evaluation.

3. There are two kinds of decision nodes: “Need model change?” and y “Need model improvement?”.

4. Detailed investigation of some important parameters of alternatives (or “Final comparison” of available ones) is performed in loop 2, and contains all the steps from the cycle in the initially designed process in Figure 2.

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5. The monitoring of the implementation project was continued after the decision was made. Loop 3 serves for the case when the decision was made and implementation began.

6. Although it is possible to exit from loops 1 and 2 with a chosen alternative (without a need for an improvement) and begin an implementation project, the process can be interrupted again in loop 3 due to some reasons (e.g. project failure or a sharp change in requirements) and DM process can be restarted. This means a return to the node "Need model change?" of loop 1, and then even to the very beginning of loop 1.

7. We also found that the selection of an implementation partner has a high importance for DM in organizations. The focal company actually considered a combination of the vendor and implementation partner as an alternative. Thus, one can consider two or more alternatives with the same underlying software but different implementation partners as separate options.

Discussion

During the last 20 years many organizations have implemented ERP systems, and are therefore forced to keep their system up-to-date and perform ERP upgrades in times of rapidly changing business environments, technological enhancements and rising pressure of competition. However, not only because of the ERP complexity, but also because of the high costs, a failed ERP upgrade project can have serious negative consequences. We believe that a proper DM process can help to control such risks.

This paper focused on developing an iterative DM process under uncertainty for ERP upgrade decisions. We revealed that not only model parameters, but also the structure of the underlying model can change in this process, and also that the ERP system provider and implementation partner form two separate aspects of the respective decision in many cases. We thus propose an improved ERP DM as an iterative analytical process which has three loops and presumes operations with unambiguous, measurable and comparable parameters. It continues as long as decision makers consider that they are not ready to make the decision, information about alternatives needs improvement and there are resources (e.g. time and budget) to continue the analysis.

This is a new vision of a DM process in ERP management verified with a practical case study. It is in coherence with the previous DM studies, however, extends our knowledge of the DM process to a repeated iterative activity. The outcome is a general process that practitioners can follow in practice. Today, IT decisions in the industry are often implicitly taken resembling this approach, but excluding details of the mathematical models, content of objectives and criteria, the number of iterations, and without the awareness of the full process design and flow. This makes the decision processes problematic, and our approach can be helpful for practical and relevant decision making.

Corporate IT DM was not well recognized in the related literature as an iterative process until now. The main outcome is the new process of DM that includes features not mentioned before: three main loops of DM, multiple repetition of loops, and possible returns to the starting point even during project execution. This process can continue at the implementation stage when a return to the starting point can happen due to certain events. One or another decision variables are being refined all the time during the DM process and this is controlled by decision makers with specified and updated thresholds, constraints, and conditions. Depending on the values of decision variables, DM can choose to proceed with the appropriate solution or continue assessment using one of the three loops of analysis. All considered, this research reveals new directions to DM in information management.

Thus, DM is ubiquitous during the ERP system lifecycle. Today's lifecycle models do not see the hidden diversity of the possible developments of ERP DM process during the ERP update. Our DM process opens new directions for ERP lifecycle study and research in different aspects of ERP DM, and especially during later lifecycle phases. The practical influence lies in acknowledging the complexity of the ERP upgrade activity in the sense of DM and the need for the organizational controls on the DM process, effective communications, and DM support methods.

This paper has several limitations, which can also provide ideas for future research. The current work evaluated the proposed decision process model and produced a new one based on a case study at an automotive company. First, further practical application of the process model in different settings, including multiple industries and countries, and thus a full artifact validation, would be necessary. This would enable empirical validation of its efficiency on a diverse set of real world examples in different industries and applications.

Second, as the previous knowledge already provides for DM processes, it would be interesting how economically efficient different models are, e.g. regarding time and effort of application, and also to include softer factors into the evaluation, including understandability.

As a future research, the underlying DM methods for managers should be evaluated and recommended for this process. We especially pay attention to techniques that allow unambiguous and robust utility aggregation of alternatives and their comparison. In this way, it is possible to produce a comprehensive methodology for ERP DM. Another research direction could be the investigation of the influence of specific criteria of the DM process on the number of loop iterations. For instance, are some of them more likely to prevent unnecessary loops or cause excessive repetition of some of them? A connected issue is how much effect different patterns of the loops may have on the overall effort and time of the DM process depending on certain DM conditions. From a descriptive viewpoint, it would also be interesting to observe the number of loops in practice, and also the stability of the formulated decision models.

Conclusion

Through developing an iterative DM process under uncertainty, we have extended the current conception of the ERP DM process in the body of knowledge as a finite one-pass activity. We argued that the process is not that simple in the current practice, which was then also confirmed via a case study. Decision makers need a better understanding of an effective process for DM in the important ERP change situations. It turned out that our initial ERP DM process was designed with the assumption that only the parameters of the decision model retain uncertainty and that the model is not changed during the process. While it was already an improvement on the current concepts of the ERP DM process where the uncertainty of parameters of alternatives is not considered at the stage of choice, we revealed more complex issues during the case study:

- We found that the parameters, criteria, and the aggregation model itself should be further analyzed and the decision iteratively improved.
- Furthermore, many loops can be identified in the DM process (see Figure 3), and a return to earlier stages of the process can happen from several points: the point of DM ("Need model improvement?") and even after that – when certain problems with the chosen solution are identified. In the latter case, a return to the very beginning of the process is possible. And this is also done through the return to "Need model change?" stage of our model.

- Moreover, our case study revealed that the ERP upgrade may be a continuous ceaseless process throughout the ERP system lifecycle. In this way, the current knowledge of DM in the ERP upgrade has been enhanced, and brings these processes closer to agile processes rather than strictly waterfall-oriented approaches.

The evaluation of the ERP DM model was performed with a real DM problem at an automotive company. During the case study, we evaluated and improved the DM process so that it matches the real ERP upgrade DM well and can assist in ERP DM in future in a more generalized way while retaining the necessary generalizability and clarity. Although it requires more empirical research, we can hypothesize that the model is general enough to be examined or applied in other industries. However, its validation needs further research and is beyond the objectives of the current paper.

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