Risk assessment in ERP projects

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ABSTRACT

Conducting Risk Management of Enterprise Resource Planning (ERP) projects is an ambitious task. ERP projects are complex undertakings for business enterprises, as the associated risk factors include myriad technological, managerial, psychological and sociological aspects. Moreover, such factors are often tightly interconnected and can have indirect effects on projects. Such features make Risk Management more difficult, uncertain and important than in traditional projects, especially in the Assessment stage.

The aim of this paper is to propose an innovative technique to support Risk Analysis in order to provide a better, more structured and systematic understanding of the major relations amongst various risk factors, on the one hand, and between risk factors and the specific effects associated with ERP projects, on the other. A real case study regarding a multinational company and involving a panel of experts and practitioners is presented to illustrate application of the method.

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1. Introduction

An Enterprise Resource Planning system is a suite of integrated software applications used to manage transactions through company-wide business processes, by using a common database, standard procedures and data sharing between and within functional areas. However, installing an enterprise system is not merely a computer project, but an expensive and risky investment, which impacts on a firm's primary and support processes, its organizational structure and procedures, the existing legacy systems, and the personnel's roles and tasks [41]. Many of the associated costs are hidden, its benefits intangible, and its effects wide-ranging, cross-functional (difficult to isolate) and "long-term" on resources and competences.

According to the estimation of the Standish Group International (SGI), 90% of SAP R/3 ERP projects run late [32], while another SGI study of 7400 Information Technology (IT) projects revealed that 34% were late or over budget, 31% were abandoned, scaled back or modified, and only 24% were completed on time and on budget [12]. One explanation advanced for the high ERP project failure rate is that managers do not take prudent measures to assess and manage the risks involved in these projects [20,39].

Therefore, the organizational consequences and risks involved with ERP projects make it all the more important that firms focus on ways to maximize the chances for successful adoption of ERP. Several studies of ERP implementations, combined with findings from earlier work on reengineering and change management, point to some of the areas where critical impediments to success are likely to occur [43]: human resources and capabilities management, cross-functional coordination, ERP software configuration and features, change management, organizational leadership [10], systems development and project management. With reference to the last factor, brand-spanking new combinations of hardware and software, as well as the wide range of organizational, human and political issues, make ERP projects inherently complex and the lack of skills and proven approaches to project management and Risk Management (RM) represents a critical risk factor [29].

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Recently a large number of models, methods and techniques have been proposed by both academics and practitioners to address the need for a structured Risk Management approach as a core activity of ERP projects [6,19,28,31]. Herein, we deal with the Risk Assessment (RA) stage of Risk Management in an attempt to contribute to the development of an effective methodology for its application and to provide a support tool for the formulation of risk treatment strategies and actions during the introduction of ERP systems. Specifically, a systems engineering theory (Interpretive Structural Modeling—ISM) is suggested to meet the needs for the analysis and modeling of causal relations amongst risk factors themselves, and between risk factors and their effects. Indeed, the ultimate aim of the research is to provide valuable input to both the risk evaluation and treatment stages.

In this regard, the aims of the paper are to:

- Adapt ISM features to meet the needs of the risk management (analysis) process in ERP projects by presenting and discussing the benefits of its application through a real case study focusing on risk factor modeling.
- Set the stage for future research aiming to integrate the proposed technique within a broader risk assessment methodology, which is to include risk effects modeling and extend the validation process to a larger number of case studies.

In the next sections, we first present the background research context on IT and ERP Risk Management, the problem of establishing a general reference framework and the existing approaches in the literature. The research objectives and methodology are then introduced and the case study presented and discussed. Finally, conclusions and indications for further developments are advanced.

2. Research background

2.1. A project Risk Management framework

In dealing with Risk Management with regard to any project, it seems worthwhile to define 'risk' as *an uncertain effect on project performance.* Thus, efficient, effective project management requires appropriate management of all sources of uncertainty within the project. Quantitative (or qualitative) Risk Assessment is a process for systematically guiding Risk Management activities by collecting and evaluating (quantitative or qualitative) data on the severity of the potential effects consequent to a risk factor (event) and its probability of occurrence.

According to the literature [11,13,16], in complex projects, Risk Management can lead to a range of project and organizational benefits, including: enhancing corporate control in terms of more effective resource allocation; increasing confidence in achieving project objectives; more precise estimates (through reduced uncertainty); improving the ability to look out for and take advantage of opportunities; minimizing surprises and unexpected events; improving chances of success; helping to avert

disasters; avoiding reworking; focusing and balancing efforts; and promoting win–win situations.

Several generally accepted approaches to Risk Management have been proposed in the literature. Some of the best-established frameworks have been outlined in the PRAM Guide [33], PMBOK Guide [28], RAMP Guide [23,34], the Australian Standard [6] and SHAMPU process [13], PRINCE2 manual [9] and SAFE approach [27]. Comparing these approaches, however, discrepancies in terminology and overlapping activities often emerge, since they stem from different views and aim to fulfill different needs. In this section we present our proposal for a Risk Management framework which tries to uniformize such discrepancies.

The framework has been drawn mainly from the PRINCE2 guide [33], the Australian Standard [6] and the PMBOK guide [28]. While inheriting the general structure of the first and second models, it also supports the operational perspective suggested by the second and third, especially regarding the identification and quantification stages.

Concerning the assessment stage, in particular, the newly devised framework is more analytical than formulations such as PRAM [33], RAMP [34] and SHAMPU [13]. The main reason for this is to resolve the taxonomical ambiguities that generally plague earlier contributions. Moreover, it incorporates and standardizes the treatment strategies presented in the RAMP [23] and PMBOK guides [28]. Lastly, the framework follows SAFE guidelines [27] well, in that it is places great emphasis on the control and reporting stages.

In accordance with the foregoing, a general Risk Management framework can be drawn up for IT/ERP projects. It consists of 7 basic activities and 4 main stages, as shown in Fig. 1.

(i) *Context Analysis*—aims to define the boundaries of the Risk Management processes (the processes to be analyzed, desired outputs and performance, etc.) in order to define a suitable risk model approach.

(ii) *Risk Assessment*—is a core step in the Risk Management process and includes:

  (a) *Risk Identification*—aims at timely identification of potential threats (internal and external risk factors) and their impact (effects) on project success.

  (b) *Risk Quantification*—involves prioritizing the identified threats according to their risk levels; this consists of two main steps:

- *Risk Analysis*—provides input to the risk evaluation and treatment stages for final risk quantification and formulation of the best response strategy. Typical inputs include the probability of a risk factor occurring, factor interdependencies, their links with potential effects, the severity of these effects and, when necessary, the difficulty of detecting them.
- *Risk Evaluation*—defines classes of risk. By selecting an appropriate, effective risk aggregation algorithm, the risk level for each risk factor identified can be expressed synthetically.
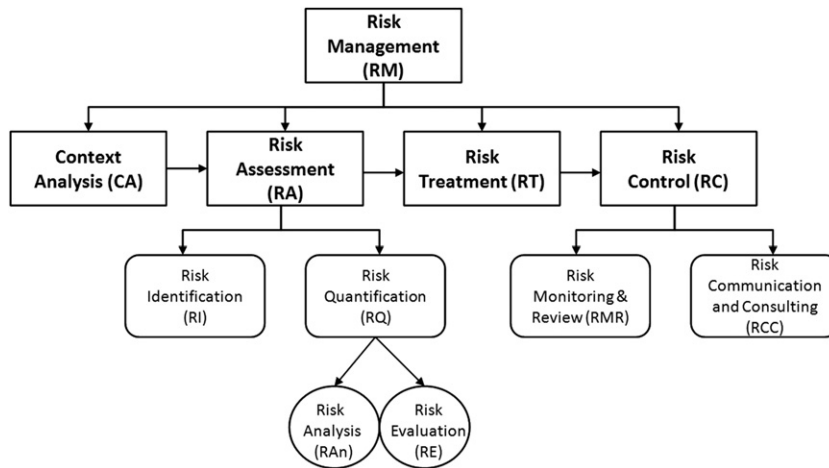
Fig. 1. A schematic framework of a general Risk Management process.

(iii) *Risk Treatment*—calls for defining an effective strategy to manage the risks associated with the various risk classes defined. Risk Management strategies consist of four classical approaches: the first is to reduce exposure to risky circumstances, the second attempts to mitigate the impact of a risk factor after it appears, while the third and fourth seek to externalize or accept the risks encountered.

(iv) *Risk Control*—the ultimate aim of Risk Management is to deal with the risks inherent in a project and thereby exercise better control over the project and increase its chances of success. The main steps in the risk control stage are:

  (a) *Monitoring and review*—each step in the Risk Management process is a convenient milestone for reporting, reviewing and taking action.

  (b) *Communication and consulting*—aims to effectively communicate hazards to project managers and other stakeholders in order to support managerial actions.

2.2. Risk Management in ERP projects

Unfortunately, formal, structured Risk Assessment methods are rarely applied to Risk Management in complex IT projects, such as the introduction of ERP systems. Enterprise-wide ERP projects are among the most critical IT projects and present new opportunities and significant challenges in the field of Risk Management [26]. Critical factors include technological and managerial aspects, both psychological and sociological. The various factors are moreover tightly interconnected and may have indirect effects on the project. Thus, applying Risk Management, in particular the Risk Assessment stage, to ERP is more difficult, uncertain and crucial than in traditional projects.

The complex structure of the system and the high number of "agents" (including risk factors) involved increase the magnitude of risk in relation not only to each single agent, but also to the interconnections between them. The structure of an RM project for an ERP system can be represented as a complex networked project in which several "agents" have to be managed properly in order for the project to succeed. The risks inherent in such projects are typically interdependent and, since interdependence does not require proximity, the antecedent to failure may be quite distinct and distant from actual disaster. The occurrence of a specific event (a first-level risk factor) in an early stage of the ERP life cycle could result in major impacts on the whole project (domino effect), and cause new risk factors to emerge in later stages of the project (second-level risk factors).

For these reasons, before attempting any Risk Assessment, it is first essential to understand risk factor interdependencies and the relationships of risk to direct and indirect effects.

To the best of our knowledge, articles proposing specific (ERP project-oriented) Risk Management approaches, methodologies and techniques are very limited. In [4] a number of key articles on the introduction of ERP systems are critically classified in order to exemplify the main issues and research approaches present in the literature and to identify areas in need of ERP Risk Management, together with the most relevant risk factors. From the review, it seems clear that, despite the great importance attributed to factors linked to project management, including Risk Management [5,14] and change management, only a few articles explicitly address these issues. Indeed, contributions to research in "Risk Management and general ERP project sections" are very limited and mainly concern the organizational or business impact of ERP systems [8]. Moreover, suitable Risk Management approaches, methodologies or techniques focused on ERPs are rarely found in the literature.

In order to extend our search for any literature contributions dealing with Risk Management issues in ERP projects, we researched the broader subject area of "ERP Risk Management". Table 1 shows the main academic works on ERP Risk Management in relation to their emphasis on the different stages of the Risk Management process. We have classified the works according to a

Table 1
Classification of articles.

	Context Analysis	Risk Assessment			Risk treatment	Risk Control	
		Identification	Quantification			Monitoring and Review	Communication and Consulting
			Analysis	Evaluation			
Sumner [36]		c			a		
Wright and Wright [40]		b					
Scott and Vessey [32]	a	b	a				
Tatsiopoulos et al. [37]		a	a	a			
Huang et al. [17]		b	a				
Zafiropoulos et al. [44]		b	a	a	b	a	a
Leopoulos et al. [22]		b					
Yang et al. [42]		a	a	b	a	a	a

[a] Low.
[b] Middle.
[c] High degree.

subjective judgment scale that takes into account the degree of detail, structuring and innovativeness: Low (some general, unstructured indications), Medium (some valuable structured indications) and High (innovative, detailed indications). What is clear at first sight is that most of the contributions concentrate on the Risk Identification and Analysis stages in a rather descriptive fashion, while only a few suggest working models or techniques for the Risk Quantification stage – particularly Risk Analysis, which as stated is the specific aim of this paper – or for defining appropriate treatment strategies (Risk Treatment).

As for Risk Analysis and Evaluation, the literature is not so clear and contributions rather difficult to interpret and classify according to these two distinct stages. Often, authors address the two stages simultaneously or in an integrated fashion, and do not distinguish between desirable outputs that are useful for preliminary process analyses and those which should be fed to the following phase of Risk Evaluation; in other instances, they even ignore one of the two stages. Some works advance general models for risk factor classification and analysis [32], but none proposes any structured methodologies useful to this purpose. In [17], for example, the authors use an AHP-based methodology to perform a very preliminary analysis and prioritize ERP risk factors. The researchers in [44] present a qualitative Risk Management application to aid project managers in assessing the importance and evaluating the potential impact of risk factors. Lastly, a systematic assessment of project risks in ERP introduction via the use of FMEA is suggested in [42].

Focusing in particular on the Risk Analysis stage, almost all the examined contributions present quite qualitative approaches and, to the best of our knowledge, very few papers deal explicitly with the problem of factor relationship analysis within the Risk Management process. Akkermans and Van Helden [3], for example, suggest a preliminary step for investigating the relationships between ERP and Critical Success Factors (CSFs) by developing a framework based mainly on intuitions gleaned from a case study [35]. The study describes how CSFs can be used to explain project performance in ERP implementations. Although they found a high correlation between the CSFs, it was through an exploratory study and they themselves recommend a more formal approach to modeling dependencies. Jing and Qiu [18] suggest an ISM approach to analyzing a set of CSFs in ERP projects. However, the work is mainly a conceptual contribution focusing on preliminary analysis of an ERP project and is not framed within a formal Project-Risk Management process.

A highly desirable development in ERP projects would be a shift towards more formal approaches, such as Quali/ Quantitative Risk Assessment (QRA), as opposed to *Concern-driven Risk Management* [15]. Indeed, by separating "facts or beliefs" about consequences from the assigned "values", and "consequences" from "actions", QRA provides more analytical and systematic procedures for organizing and applying scientific and engineering knowledge to improve "rational" (consequence-driven) decision-making under conditions of uncertainty. Using explicitly documented assumptions, knowledge, facts and available data to assess risk and potential alternatives makes it possible to identify specific areas of disagreement and to either resolve them or note which assumptions may affect results.

Herein, we suggest applying more quantitative RM methodologies and techniques in a formal ERP Risk Management framework. In this direction, herein we show how ISM can, in various ways, provide effective support for the Risk Analysis stage of an ERP project.

3. Research objectives

In the following we propose a technique to enhance Risk Analysis by achieving a better understanding and a more structured, systematic model of the various relationships between the risk factors/effects associated with ERP projects. The major benefits expected from this work are:

(a) A more objective and systematic way to analyze the interdependencies between risk factors and effects in ERP introduction projects.

(b) Enabling a collaborative approach to Risk Analysis, potentially including subjective judgments in a more structured format.

(c) An effective preliminary analysis and classification of risk factor dependencies to help managers in project Risk Assessment, treatment and control (dependent factors are important for ex post control of residual risk, whereas independent factors are important for ex ante control and risk reduction).

(d) A graphical representation of risk factor and effect interdependencies to help managers understand the causal links among the selected variables, both in the assessment of a global risk index for each factor and in the formulation of a suitable risk treatment strategy.

(e) An easily understandable and usable technique to enable anticipating user errors and provide a rapid response, as well as the ability to modify or expand the model.

Given the explanatory nature of the research, a case study approach was adopted in order to facilitate understanding of the problem and to test ISM applicability in an actual project. The case study regards a multinational company operating in the field of Electric Power Systems and Alternative Energy Systems that is implementing an enterprise-wide ERP (Oracle).

As previously mentioned, for the sake of simplicity and clarity, we have limited the focus to the interdependencies among ERP risk factors. Thus, ISM is used to assess the interdependencies among the various risk factors and build an "ERP project" fault path, whose aim is to support risk analysis and the successive steps in ERP Risk Management. However, it is important to note that this does not compromise the value of the study in terms of innovation, usability and utility, since the technique could also

provide important information about how risk factors lead to risk effects. A structural graph of their relationships, for example, could be drawn in subsequent steps of the research in order to provide the basis for the evaluation stage and accurate assessment of each factor's risk level. For this reason, in the following risk effects will be included in the ISM modeling (data collection tools, risk factors-effects matrix), though they will be excluded from the data analysis and discussion.

4. Research methodology

The goal of Risk Analysis (RAn in Fig. 2) is to examine risk factors in order to provide a better understanding of the features of any identified risks and enable a more reliable estimation of their probability of occurrence, their interrelationships and impact on the overall project. RAn is functional both to the Risk Evaluation stage (RE in Fig. 2), to perform Risk Quantification, including the interdependencies amongst risk factors, and to the Risk Treatment phase, to differentiate the risk response strategies according to the intrinsic features of each risk factor.

Risk Analysis strategies, methodologies and techniques may vary according to the risk, the purpose of the analysis and the level of protection required for the relevant information, data and resources. However, while the evaluation stage is formally more structured and well-defined in the literature, RAn remains rather more general, as little work has been done on considering the interdependencies amongst risk factors.

The following sections address the identification and modeling of the interdependencies among risk factors and their causal relationships with the effects via application of the Interpretive Structural Modeling.
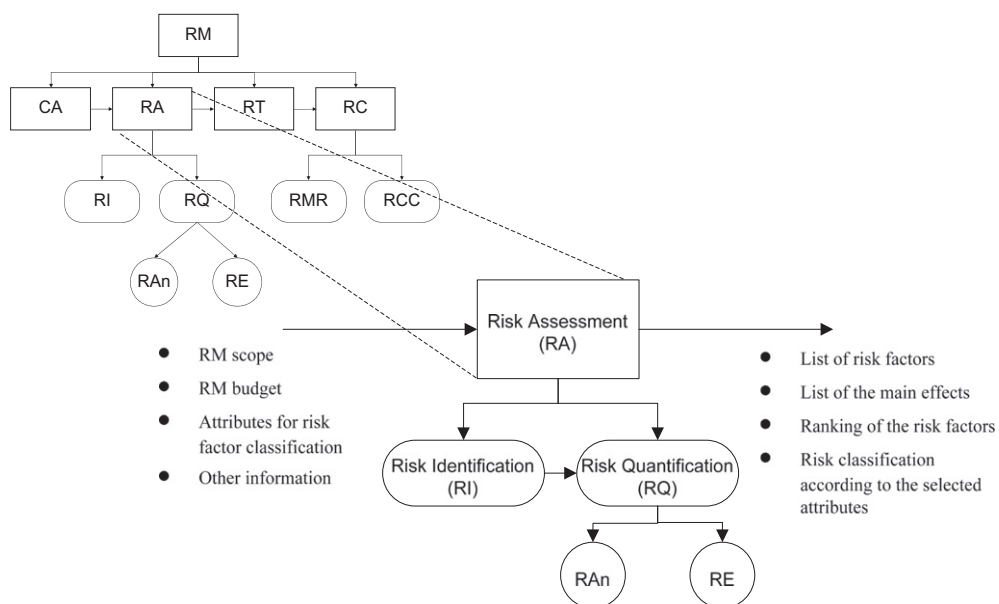

Fig. 2. Risk Assessment.

4.1. Value of ISM for ERP Risk Analysis

As previously stated, ERP Risk analysis has to be framed in a more general Risk Management process, which should ideally begin in the Project Preparation phase. This kind of activity, within the planning of the RM process, should support managers in a decision-making process which has to face real situations that deal with ill-defined and interdependent dynamic problems—that is, with highly complex systems. The technique should improve their perceptions of complex systems in the context of their own decision-making variables and also enable a profound (rather than superficial) agreement.

The conceptual requirements of such a technique can be divided in two main classes: *functional and non-functional*. The firsts concern the basic activities which the techniques should support:

- *Identification*. The technique should assist the identification of relationships between the risk factors and causal links between risk factors and effects effectively.
- *Modeling*. The technique should support managers to structure, model and interpret causal relation between risk factors and then with the final effects. The method should allow to model dependencies (how a factor lead to another and how structuring the relationship function), strength of the links (likelihood that if factor A happen, also factor B occurs), triggers (which are the independent risk factors or other external trigger events) and support a graphical representation of the causal event chain, which goes from each risk factor to all the connected risk factors and finally effects (causal risk path).
- *Analysis*. The technique should support managers in interpreting the results in order to provide valuable input to the risk evaluation phase in terms of: strengths of the paths between each risk factor and the risk effects; definition of an ad-hoc path index for the "path risk" in order to include it in the risk evaluation phase; a first classification of the risk factors; a graphic representation of the causal relationships, etc.

At the light of the previous highlighted requirements, among the various techniques developed to guide the analysis of a system/project [2,14], Structural Modeling (SM) techniques, and ISM in particular, seem to be quite promising for application to ERP projects since they can provide managers with:

- A standard, intuitive procedure for collecting and analyzing expert judgments on the dependencies between the selected variables.
- A first classification of the variables according to the criteria of "dependence" and "driving power".
- An assisted graphical hierarchical representation of variables.

Non-functional requirements, instead, specify criteria that can be used to judge the operation of a system or a technique, rather than specific behaviors: accessibility (Documentation, legal and licensing issues); usability (by target users); efficiency (resource consumption, time, etc.); effectiveness (resulting performance in relation to effort); extensibility (re-configuration management, adding features); quality (e.g., faults rate); scalability (horizontal—number of factors, vertical—modeling details); software support; compatibility (with other techniques); stability (of results).

In particular, the main advantages of ISM compared with other general techniques for complex system modeling and analysis (such as system dynamics) and especially to other structural modeling techniques [21], concern with this second class of requirements. In fact, the Usability of the technique make it suitable to be effectively adopted in risk based group decision-making during the very early stage of the RM process in the ERP project preparation stage. Regarding the non-functional features of ISM, we can notice:

- *Input flexibility:* the method can incorporate empirical data when it is available (*Quantitative emphasis*) *or* can focus on inexact, subjective input producing meaningful output (but not precise, quantitative forecasts of behavior) (*Qualitative emphasis*).
- *Group orientation*: Supporting group processes, assisting the formulation of subjective judgments and allowing ease of use and communicability are fundamental features for this kind of application.

4.2. ISM application to ERP risks

Structural Modeling (SM) processes generally operate as interpretive learning processes involving the participation of various agents working collectively on a problem, which is defined in terms of a system (elements, interconnections, etc.). The process starts with certain system-related data, ideas, skills, and/or knowledge possessed by the various participants and ends with their gaining an enhanced understanding of the system, both individually and collectively. Finally, SM holds the promise of translating a completely intuitive process of model building into a more systematic approach and enhancing communication within heterogeneous groups [21].

ISM is a well-established, computer-assisted methodology in the SM process class for constructing and understanding the fundamentals of the relationships between elements in complex systems. The ISM method provides a structured approach to interpreting group judgments about whether and how items are related. The ultimate the aim is to extract an overall structure connecting such items from the identified relationships and plot them in a digraph model for interpretation [30].

The application of ISM usually involves the following steps [25]:

- *Step 1. Organizing an ISM implementation group.*
  First, experts from different areas throughout the firm are chosen for their relevant knowledge, skills, and backgrounds to form a group. The wide-ranging skill-set of this group is critical, as ERP should ideally be embedded in the company's operations throughout the firm.
- *Step 2. Identification of Elements* (*risk factors/effects*).
  A crucial step for the subsequent stages of analysis,

risk factors and potential risk effects for ISM application have to be identified as completely as possible to provide a material base for the following steps.

- *Step 3. Structural Self-Interaction Matrix (SSIM).*
  The first step in analyzing the relationship between risk factors is to determine which factors lead to others. The SSIM is built up based on these "contextual relationships". People are asked to fill out simple matrices (such as Tables A1 and A2 in Appendix A) in order to assess how directly one risk factor leads to another and to what effect. Directed relations are hypothesized among the risk factors. The matrix thus provides an initial impression of how, in what order, and through which other factors, the various risk factors might ultimately be the source of unrealized objectives. Here, the adjective "directed" refers to the need to specify the path(s) of the relationship (if any) between any two risk factors—e.g., from A to B, from B to A, in both directions between A and B, or A and B unrelated. The answers to whether or not a relation exists (YES if one factor leads to another; NO if it does not) are then analyzed and potential discrepancies resolved in an open discussion with other experts to avoid potential loops, since a Directed-Acyclic-Graph (DAG) is necessary for the ISM procedure (a Delphi approach involving the respondents and/or other experts can be useful to this aim). A common SSIM table is finally compiled.
- *Step 4. Reachability Matrix.*
  The SSIM is converted into a binary matrix by substituting the filled-in values with 1, if YES, and 0, if NO. Then the transitivity propriety is checked, so if risk factor i leads to j and j leads to k, then i must lead to k. The reachability matrix is then modified and the data processed.
- *Step 5. Classification of Elements (risk factors/effects).*
  Factors are classified according to their "dependence" (how many factors they are influenced by) and "driving power" (how many factors they influence). This aids managers in assessing the import of a specific risk factor, even if it has no evident or measurable effects. Fig. 3 shows the four risk factor classes (I Autonomous;

II Dependent; III Linkage factors; IV Independent).
- *Step 6. ISM level partitioning.*
  Two sets are associated with each element of the system: the Reachability Set, that is, a set of all elements that can be reached from the element; and the Antecedent Set, that is, a set of all elements that the element can be reached by. The top element of the hierarchy will not reach any other element, so it is identified and separated. Then the reachability matrix is converted into the lower triangular format. This is an algorithm-based process, which provides for the grouping of risks into different levels, depending upon their inter-relationships. This provides a multilevel interpretive structural model in which the relations among risks are clarified.
- *Step 7. ISM risk factors/effects model.*
  A directed graph of the interdependencies amongst risk factors and effects is then drawn up (Fig. 4). As ISM graphs have no cycles or feedback, the elements (risk factors/effects) are arranged in a purely hierarchical pattern and modeled as an ERP fault path.

5. Case study

5.1. Company profile

The ISM methodology has been applied to support Risk Analysis in a real ERP project to assess the interdependencies among the project risk factors and build an "ERP project" fault path. Risk Analysis, as any planning stage in a Risk Management process, should be integrated in the very earliest stages of the implementation process (for example: the preparation phase; see Fig. 5).

The case study regards a multinational company (whose identity has been withheld for reasons of privacy) operating in the field of Electric Power Systems and Alternative Energy Systems, which recently began rolling out a new (Oracle) ERP system. In recent decades, the company, one of the world's leading manufacturers of
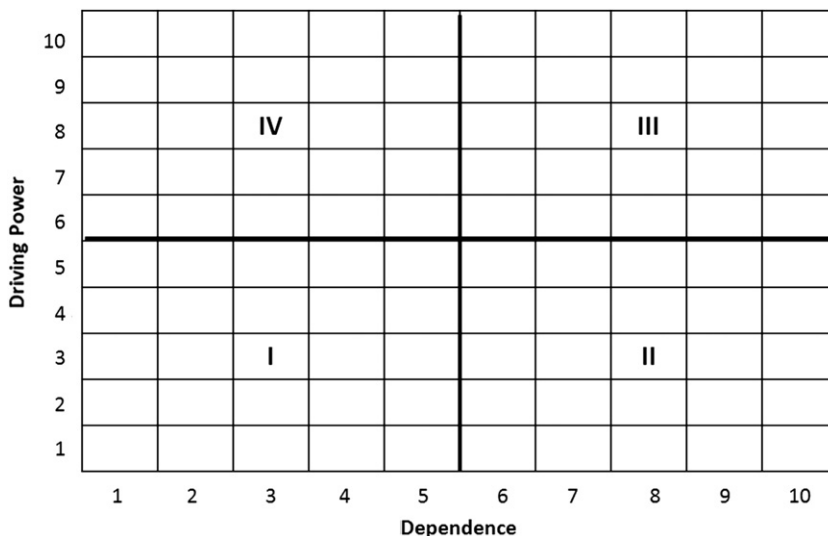
Fig. 3. Dependence-Driving power graph.

power-conversion equipment for the telecommunications, networking, and technology markets, has undergone impressive expansion due to core business growth and the penetration of new markets, including entry into new application fields fostered by several acquisitions. Therefore, an "IT Re-alignment" project was launched in order to homogenize the information and procedural structures of the new plants with the existing corporate ones. This project also included implementation of a new (Oracle) ERP system.

The company's stated reasons for implementing the new ERP system were mainly expected IT benefits: consistent data in a shared database; open architecture; integration of people and data; reduction of update and

repair needs for separate computer systems; achieve better integration with the corporate body. However, business and operational benefits were also pursued: operations efficiency; process standardization; and reduction of staff positions. The project plan consisted of 3 main stages: Concept, Implementation and Post-implementation (Fig. 5). More in detail, these consisted of:

Preparation Phase (*concept*). This was part of Strategic Planning and consisted of defining the project's scope and staff (key users and consultants). In this phase a project plan was drafted and a kick-off assessment meeting held to establish the project start. A project communication tool was also set up: a Web site on the corporate SharePoint-based Intranet, on which all project communications and documents were to be posted. An explicit selection process was not performed in the project.

The project was then driven from system deployment to final stabilization (*Implementation*) through a Solution phase, three Conference Room Pilots (CRP1, 2, 3), and a Preparation to Rollout phase:

Solution Phase I. Sometimes called CRP0, this included key user training and tests of ERP software solutions. The discrepancies between the "as is" business processes status and the current corporate practices were examined. At the same time, training of key users began and a CRP1 test was also prepared.
CRP1, CRP2 and CRP3. These three tests were conducted in order to identify any discrepancies or bugs and

Fig. 4. Hierarchical pattern of relationships.

Fig. 5. ERP project phases.

resolve them. Legacy system data were converted and migrated to a new database. When CRP3 began, end-user training also commenced.

Prepare Rollout. All discrepancies and bugs had to be resolved and the solutions checked. User profiles were established and end-user training was completed in order to ready the system to "go live".

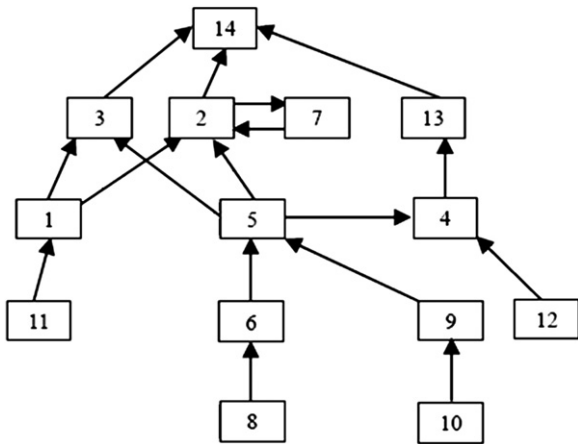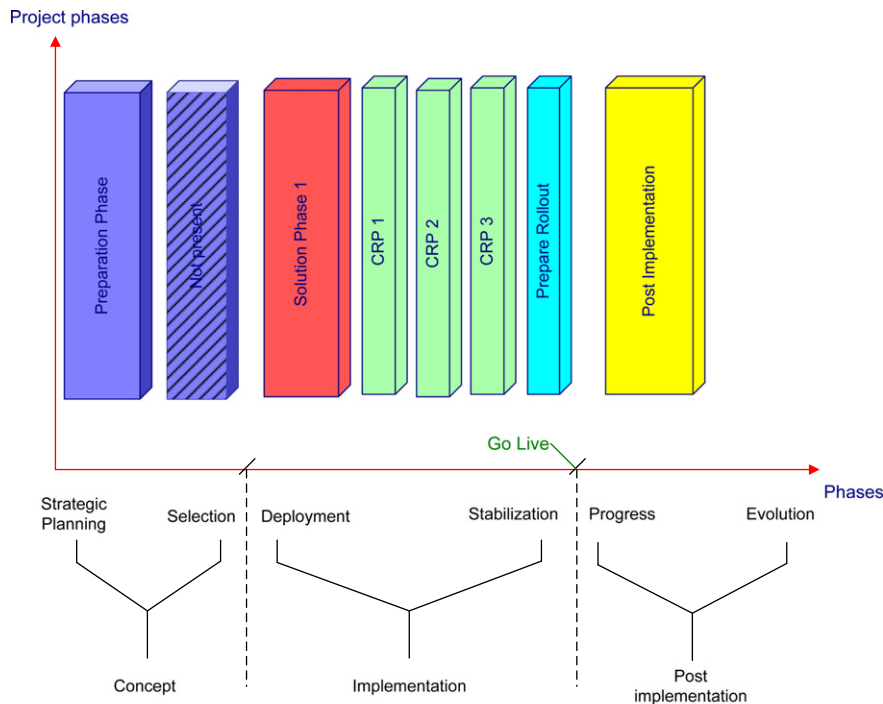The next two stages included Going-Live and post-implementation activities (Progressive and Evolutive Maintenance):

Going Live consisted of cutting-off of any legacy systems. All transactions were stopped in order to preserve data integrity until data migration was complete.
Post Implementation. A support system was provided to help users in post-implementation activities. Systems performance was systematically monitored and continuous improvement actions planned and carried out.

5.2. Data collection (step 1)

The first phase of ISM procedures consists of selecting the experts who will make up the ISM implementation group. For the present investigation a highly qualified panel of academic experts and practitioners was formed; their main task was to determine how the various ERP risk factors influence each other.

Several members (Table 2) of the Oracle Implementation Team were selected for the interviews; a structured interview format was defined and followed for each. Moreover, two academic experts were appointed to manage the ISM process. A Delphi-based [1] process was adopted in order to achieve convergence of the experts' judgments. First a preliminary structural model was defined by each participant, then the ISM process was reiterated until consensus reached and all loop and transitivity problems were solved.

5.3. Identification of elements (step 2)

Identifying the risks factors to include in the analysis can be quite challenging for managers, especially because there are different ways in which they can be described and categorized [7]. Often "risk factors", "Critical Success Factors" and "Uncertainty factors" are used to convey the same concept. Moreover, project success/failure depends on how and by whom it is determined [38].

For the current application, we refer to the general classification of global failure causes and risk defined in [4]. The following four-level classification of IT project failure was adopted [24]:

(a) *Process failure*, when the project is not completed within time and/or budget.
(b) *Expectation failure*, when the IT systems do not live up to user expectations.
(c) *Interaction failure*, when users attitudes towards the IT are negative.
(d) *Correspondence failure*, when there is no match between IT systems and the planned objectives.

Fig. 6 summarizes the 19 risk factors, 10 effects and the 4 main project failure macro-classes (see Table 3 for a more detailed description of the risk factors).

5.4. Data analysis (step 3–4)

In order to build a complete causal risk path, any study of interdependencies should concern both the risk factors' inter-relationships and the relations between risk factors and effects. In the present study, the identified variables were grouped into two categories corresponding to these two aims, and two different matrices were constructed (Fig. 7), one for the former aspect, and one for the latter.

Questionnaire respondents were asked to indicate the influence of each risk factor, firstly on the other risk factors and then on the risk effects, as perceived. Then the matrices were compared and any conflicts resolved according to the Delphi process mentioned above. When a unique SSIM matrix was achieved, transitivity and loops were checked, and any problems resolved. The final result was a conclusive Reachability Matrix.

Given the demonstrative nature of the case study, the next stage of the work focuses only on part A of the matrix, i.e. the dependencies amongst the risk factors. However, the process can similarly be applied to those between the risk factors and the risk effects.

Table 2
Surveyed subjects.

ID.	Position	Role in the ERP project team	Time with company (years)	Number of previous ERP project
1.	Senior production manager	Project manager	More than 10 years	2
2.	Financial manager	Financial analyst	Less than 1 year	6
3.	IT manager	Super user	Less than 1 year	6
4.	Traffic manager	Super user	Less than 1 year	0
5.	Chief accountant	Super user	5 years	0
6.	Sourcing manager	Super user	5 years	
7.	Planning	Super user	6 years	0
8.	Manufacturing engineering manager	Super user	6 years	1
9.	Quality manager	Super user	More than 10 years	1
10.	Production planner	Super user	Less than 1 year	0
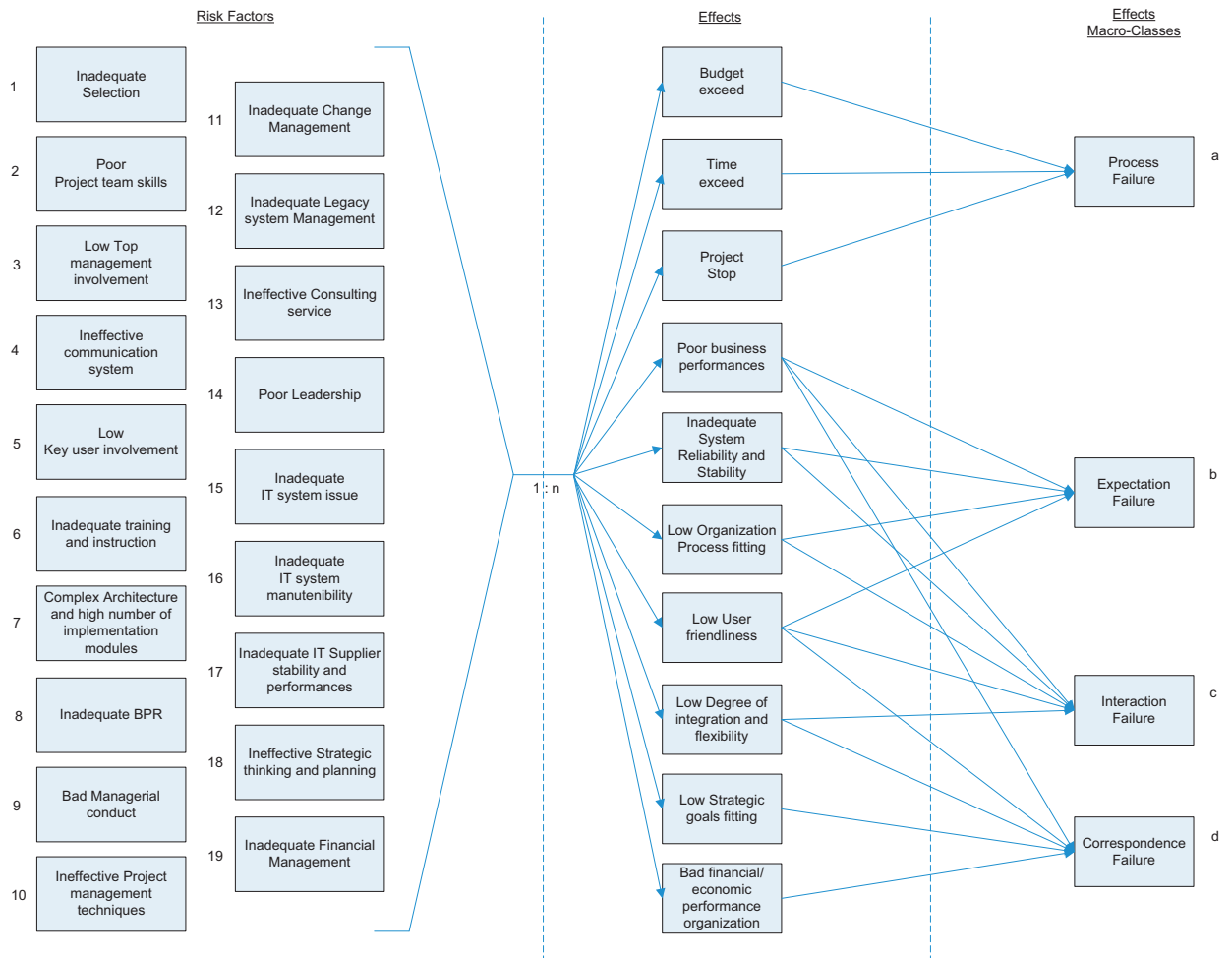
Fig. 6. Risk factors, effects and project failure macro-classes [3].

5.5. Risk analysis results (step 5–7)

Some rather interesting information can be obtained from some simple processing of the Reachability Matrix.

(A) Step 5 of the ISM process, for example, provides a first qualitative classification and interpretation of risk factors according to their dependence and driving power. This can give managers and researchers a better understanding of the risks in ERP introduction projects and suggest additional information to assess the probability of the risk factors occurring, evaluate the risk associated with each factor, and select an appropriate response strategy. This is valuable both in understanding the true nature of the factors, and to enable better assessment of the risks involved with a specific factor, including its indirect effects on other risk factors (snowball effect).

As Fig. 8 shows, the ISM classification suggests 4 main groups of risk factors according to the respective dependence and driving-power values: *Independent factors* (*High driving power—Low dependence*); *Autonomous factors* (*Low driving power—Low dependence*); *Linkage factors* (*High driving power—High dependence*) and *Dependent factors* (*Low driving power – High dependence*).

The case study yielded the following:

Independent factors: Poor project team skills (R2); low top management involvement (R3); poor managerial conduct (R9). These factors are characterized by high driving power and low dependence. This means that they have a wide-ranging influence on other project risk factors (they lead to and enable other potential risks), and a snowball effect is likely to be triggered if and when they occur. For this reason, the risk level associated with these factors is very high, and managing them should be a priority for the project managers, since successfully controlling them will reap significant benefits for the entire project.

Autonomous factors: Complex architecture and high number of implementation modules (R7); ineffective project management techniques (R10); inadequate legacy system management (R12); ineffective consulting services experience (R13); poor leadership (R14); inadequate IT system issues (R15); inadequate IT system maintenance (R16); inadequate IT Supplier stability and performance (R17); ineffective strategic thinking and planning (R18); inadequate financial management (R19).

Table 3
Description of the risk factors.

Inadequate selection	Selecting the most suitable software package solution is a key concern: if wrong choices are made, the company will be faced with either a mismatch between the package and business processes and strategies, or the need for major modifications, which are time-consuming, costly and risky. Both vendor and package have to be evaluated through a structured multi-criteria approach (functionality, technology, support, costs).
Poor project team skills	Very few organizations have the in-house experience to run such a complex project. Usually, outside contractors must be called in to manage such a major undertaking. The team's size, skills and experience are critical for correct project management, since bottlenecks (which can cause slowdowns and schedule slippage), as well communication problems can occur. Internal/external cross-functional and interdisciplinary skills in IT/ERP projects and business processes management are necessary.
Low top management involvement	ERP impacts on a firm's primary and support processes, on the organizational structures used to coordinate these processes, and on compatibility with existing (IT) systems. If top management is not actively backing an all-pervasive project such as ERP implementation, there is little hope for its success.
Ineffective communications system	It is critical to communicate what is happening, including the scope, objectives and activities of the ERP project. The team members should participate in regularly scheduled meetings, draft regular status reports, and utilize a common repository for knowledge objects. Standards for submitting information should be developed along with a formal knowledge coordination procedure.
Low key-user involvement	User involvement is crucial to meeting expectations. Key users should be convinced of the system's usefulness; they must moreover develop confidence and expertise, so that they can aid future users in training sessions.
Inadequate training and instruction	ERP training is important, but when it comes to budget, it is usually neglected or cut when projects are overrun. With reduced training employees do not learn how to use the system properly, which can create a complicated chain of problems due to the integrated nature of the system. Qualified personnel will be required to train the actual end users in the deployment stage.
Complex architecture and high number of implementation modules	The number of implementation modules increases project complexity in terms of cost and time estimates, parameterization, specification of requirements, hardware needs, business process reengineering activities, and the organizational units involved. When the new system is intended to run in multiple sites, it may be difficult to define all requirements accurately, particularly if different sites serve different customers or have different policies and procedures.
Inadequate business process reengineering (BPR)	To reap the full benefits of ERP systems, it is imperative that business processes be aligned with the ERP systems, since the literature on both reengineering and ERP implementation have shown that, in and of itself, ERP cannot improve firm performance unless the firm reengineers its business processes for the ERP systems.
Poor managerial conduct	Firstly, a clear definition of goals and objectives is necessary: any unplanned expansion (scope creep) typically causes the project to go over time/budget. Good management also improves user expectations and helps in planning the training of people in the use of the system.
Ineffective project management techniques	Novel combinations of hardware and software, as well as a wide range of organizational, human and political issues make ERP projects inherently complex, thereby requiring significant project management skills and the adoption of *ad hoc* techniques for IT/ERP projects.
Inadequate change management	System implementation often requires changing behaviors within the organization; if significant, such changes can pose high risk, in that the users may reject the system.
Inadequate legacy system management	Technology bottlenecks can occur when designers try to implement bridges between ERP modules and legacy applications. Improperly defined interfaces, or interfaces from one technology to another, can result in increased complexity of testing, adverse effects on the systems being interfaced with, and a failure to meet the project schedule.
Ineffective consulting services	Consultants may be required to help choose the right software vendor(s) and the best approach to implement ERP, to support change management initiatives, in the introduction of the database management system (DBMS) and often to act as "change agents" right from the project's start.
Poor leadership	To overcome organizational inertia and resistance to change, Functional and Technical Leader(s) are usually needed. They should possess both the relevant expertise and information and the appropriate hierarchical power and control over resources so that they can make and implement better decisions in the face of significant uncertainties.
Inadequate IT system issue	The software's technical features must be studied before addressing matters of implementation, and their impact on business processes assessed. Such features include functionality, user friendliness, portability, scalability, modularity, versioning management, simple upgradeability, flexibility, security, presence of a complete guide, a procedure manual to help users, and data accuracy.
Inadequate IT system maintainability	ERP maintenance and upgrade activities are crucial to organizations using ERP.
Inadequate IT supplier stability and performance	In typical "package implementations" the user becomes dependent upon the vendor during the introduction stage. Other factors, such as assistance and updates, questions about support to maintenance, consulting services, cooperation with other consultant companies, and so forth, all involve financial considerations that have to be addressed.
Ineffective strategic thinking and planning	The organization must decide why an ERP system should be implemented and what critical business goals the system will affect. Senior executive support is necessary in order to enable aligning the IT strategy with the organization's business strategy.
Inadequate financial management	Economic and financial strategic justifications for ERP are always necessary, because incorrect global costs analysis might impact on ERP adoption and lead to failure of system implementation projects or even bankruptcy.

Fig. 7. Risk factors-effects matrix.

Fig.8. Risk factor classification.

These autonomous factors are characterized both by low driving power and low dependence. These factors are more isolated; they are weak drivers and weak dependents, and consequently relatively disconnected from the system. By inspecting their profiles in the case study, it can be seen that they mainly belong to the categories of: Project Management and IT Technical Issues. Finally, Financial Management and Strategic thinking and planning revealed to be transverse project dimensions belonging to two different groups.

Dependent factors: Ineffective communications system (R4); low key user involvement (R5); inadequate training

and instruction (R6); Inadequate BPR (R8); inadequate change management (R11).

Factors R4, R5, R6, R8, R11 display the highest degree of dependence and the lowest driving power, so they are situated at the top level in the model and are logically found in the cluster of dependent factors. This indicates that the communications system, as well as key user involvement, training and instruction activities and change management are amongst the most critical factors, highly dependent on how well the project team manages the overall project. Accordingly, an important consequence is that the risk level associated to each risk factor was consistent with the actual dependency on other factors as well.

Linkage factors (high driving power and high dependence). The case study did not reveal any factor in this group. Despite the absence in the specific case application, theoretical consideration of the features of these factors could nonetheless be important and useful to managers. Linkage factors are usually critical, since any actions on them will have a spread effect on several dependent factors (which could involve a bias on the upper-level variables). Moreover, any risk management actions undertaken could produce a feedback effect and thereby cause system instability. If not properly managed, they could disturb the system and the entire risk management process. Therefore, careful management of such factors, when present, represents a highly complex task of critical importance to the Risk Management process.

(B) Lastly, from the reachability matrix it is also possible to define a preliminary graph of the relationships (Fig. 9; see also steps 6 and 7 in Section 4.1). Unlike in ISM, where factors are arranged bottom-to-top from lower to higher dependency, the case study representation has the factors with the highest driving power at the top level, while factors with the lowest driving power and high dependence are at the lower levels. This is mainly due to the ultimate aim of the analysis: a causal risk path directed from cause to effect, to act as an aid to risk evaluation.

Such representation of relationships is useful both in order to identify loops or solve potential problems in the model structure during the ISM process, and in order to better understand the complexity of the dependencies among the factors and effects.

The network of relations between the risk factors and effects can be very complex, as evidenced by the Reachability matrix. It may also be used as the basis on which to build a risk evaluation algorithm, which can incorporate the risk factor interdependencies.

To support managers in interpreting the relationships, we mapped a simplified structural graph to show only the relationships between level n and level n+1. Risk factors are drawn according to their degree of dependency (how many factors they depend on) and driving power (how many factors they lead to), with increasing dependency from left to right. This kind of representation can facilitate understanding of the graph and its relations and help to distinguish groups of similar risk factors.
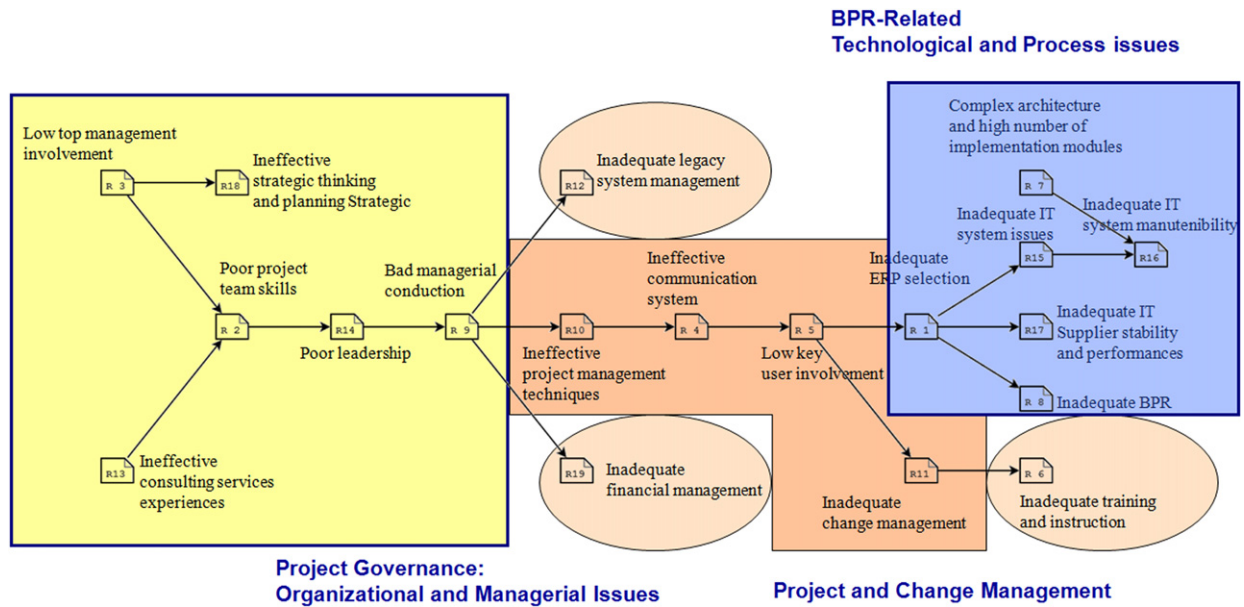
Fig. 9. Risk factors, effects and macro-classes of effects.

In the case in question, three macro-classes of factors have been identified: factors linked to Project Governance, factors in the Project and Change Management group and BPR-related factors. The position of the Project Governance factors in the model emphasizes their utmost importance, as they profoundly affect other aspects of the project, such as Project and Change Management and BPR-related and Technological Issues. Indeed, effective governance, in terms of top-management involvement, consulting service experience and performance, team skills, leadership and managerial conduct, not only helps in defining and achieving project goals and avoiding problems and conflicts, but also contributes to motivating and driving effective Project and Change Management.

The model also suggests that factors in the Project and Change Management group influence factors related to the technical and process aspects, such as ERP selection, IT system issues, supplier stability and performance, BPR, system architecture and maintainability.

Three isolated factors emerge from the case study: Legacy System Management, Financial Management and Training and Instruction. While this last factor is theoretically quite closely related to the main Project and Change Management group, the other two factors seem to be conceptually autonomous and require specific measures for proper management of financial aspects and any existing legacy systems.

5.6. Usefulness of ISM outputs for Risk Evaluation

Simple processing of the Reachability Matrix can provide effective support to managers for integrating dependencies into the Risk Evaluation algorithm. If we consider, for example, using an FMEA approach [42] to prioritize the ERP risk factors, the Risk Priority Number (RPN) for each risk factor is usually based on three main aspects: Severity (S), that is, the outcome of failure; Occurrence (O), the chance of failure; and Detection (D), the likelihood that a failure not be detected by customers, or in other words, the difficulty of detection.

$$RPN = S \times O \times D \tag{1}$$

The dependencies among the risk factors is usually difficult to include in this kind of risk evaluation. Indeed, when the probability of occurrence and the associated consequences are not directly measurable and thus need to be estimated (in most cases based not on statistically meaningful data, but on expert opinions instead), it is difficult to include dependencies in the Occurrence Probabilities.

One possible modification to the FMEA standard RPN index is the following:

$$RPN = S \times O \times D \times K \tag{2}$$

where K is a proxy indicator (dependency index) of the interdependence between each risk factor and the other ones. This would allow considering risk factor interdependence in the RPN evaluation.

Depending on the specific needs of the project, the possibility of applying different methods for estimating the K index can be considered. A first possibility is to assign a discrete score (accordingly to the scale adopted for S, O and D) to each ISM factor class (e.g. 1 to completely isolated factors; 2 to autonomous; 3 to dependent, 4 to linkage factors and 5 to independent). Otherwise, in order to avoid using fixed scores, we can also consider using – for each risk factor – the ratio between the number of dependent factors and the total number of related dependent and driving factors.

$$K_i = \frac{no. \ RS \ \text{factors}}{no. \ AS \ \text{factors} + no. \ RS \ \text{factors}} \tag{3}$$

where:

i is the Risk Factor Number;
RS is the Reachability Set; and
AS is the Antecedent Set of risk factor *i*.

For a definition of RS and AS see step 6 in Section 4.

The higher the *K*-index, the stronger is the potential snowball effect (impact) of a risk factor on the other factors; this would mean a higher RPN.

Obviously, we could also design more complex and accurate indexes in order take into account a wider reachability set (e.g considering the number of all the risk factors which are reachable from the risk factor and not just those directly connected). Finally, we can hypothesize to penalize the index in relation to the distance of each reachable risk factors from the factor we are measuring.

6. Conclusions and future research

This paper seeks to respond to the need to understand and model the interrelationships among project risk factors—a need typical of all Risk Management processes and particularly relevant with regard to complex projects such as ERP system introduction. To date, the research on such issues is quite meager. This lack has prompted the authors to develop, propose and apply a suitable methodology in order to represent the structural relationships amongst the risk factors involved in both the Risk Evaluation and Risk Treatment stages of RM.

The contribution of this work is to adapt and apply the Interpretive Structural Modeling technique to Risk Analysis in order to provide a more structured, systematic understanding of the major relationships among risk factors within ERP projects. This can guide managers during risk quantification and mitigation.

ISM provides managers with a support technique to help them identify, understand and model risk factor relationships, identify the most critical areas in need of attention and, if necessary, derive quantitative indicators of "risk dependency" to include in the risk evaluation algorithm.

The main findings appear to satisfy all the requirements set forth in the research objectives. The value and usefulness of the suggested ISM application in a typical Risk Analysis process can be expressed in terms of:

- *Risk Knowledge elicitation and structuring*:
  ISM forces users to systematically analyze every potential link among the identified risk factors, thereby avoiding their forgetting, neglecting or underestimating even the most uncommon or unusual ones. The technique also enables a highly valuable inter-functional, collaborative approach to Risk Analysis, which accounts for subjective judgments in a more structured format. Indeed, the Risk Analysis approach requires the involvement of different actors to identify and assess risks and develop management strategies: combining ISM and the DELPHI approach effectively supports this process.
  In short, the ISM process helps transform unclear, poorly articulated mental models of systems into visible, well-

defined models [30]. The out-coming knowledge is compiled in a well-structured format, which is suitable for inclusion in an RM database and then used to generate a Risk Assessment Report (an informative description of the nature and level of project risks, which becomes the functional input to the Risk Treatment stage).

- *Variety of risk information modeling, processing and reporting forms*:
  ISM provides users with a variety of information for the subsequent stages of the Risk Management process (i.e. Risk Evaluation and then Risk Treatment). The information furnished by the Reachability Matrix, for example, allows synthesizing different indicators of "risk dependency", which could enable more accurate evaluation of risk factor priority (RPN or similar) – an invaluable feature for any Risk Evaluation involving strongly interrelated risk factors, such as in complex IT projects (ERPs).

A directed graph of risk factors and effects interdependencies (similar to a Fault Path) can also be constructed in order to improve and facilitate interpretation of the identified relationships; the graph can then be used as input to the next stage of Risk Evaluation. The graph can also simplify the task of having the Risk Evaluation algorithm take into account multiple causal paths from each risk factor to any potential effects in order to prioritize risk management actions.

Moreover, ISM makes it easier to formulate a Risk management Plan, since the classification of risk factors according to "dependence" and "driving power" enables differentiating risk management action according to class.

Lastly, ISM is generally well-supported by easily understandable, usable software tools which can support managers in error detection, matrix checks, model modifications, etc. Software packages that automate the ISM process are freely available and can be adapted for such applications.

Summing up then, the Risk Analysis approach suggested herein, on one hand, provides a methodological aid, that is, a tool supporting a specific stage of the Risk Management process, and on the other, enables a preliminary and qualitative Risk Assessment. The information gathered by using ISM can in fact enable decision-makers to better quantify the inputs to the Risk Evaluation stage by defining the paths of risk factors, estimating the probabilities of their occurrence and their impacts on final outcomes, and finally facilitating the process of devising suitable strategies to respond to risks. Furthermore, it also provides an enhanced preliminary assessment of the risks in a project through a better understanding of risk factor/effect relationships and their qualitative classification. Indeed, the framework can help managers understand risk-related information in complex projects (the case study analyzed 19 risk factors to improve awareness of their enablers and account for their dependence/driving power in the final evaluation). Lastly, we have suggested some possible modifications to the RPN standard index in order to enable accounting for risk factor interdependencies.

The applicability and usability of ISM techniques for Risk Analysis has been tested through the case study of an ERP implementation project within a multinational company. Interpretive structural modeling (ISM) has been employed to understand the interrelationships among the risk factors and, ultimately, draw a causal risk path.

A highly qualified panel of experts and practitioners followed a Delphi procedure to determine how the most relevant ERP risk factors influenced each other. A total of 19 risk factors were investigated and finally classified in order to provide input to the following stage of risk evaluation. In general, such information provides company managers with a better understanding of project risks and can be used for both preliminary (since this stage does not yet consider any probability or final impact of the risk factors) and qualitative (since it is based on subjective expert judgments) Risk Assessment. It moreover represents a starting point for assessing the risk factors' probability of occurrence, as well as their final impact and the degree of dependency to consider in the following stage of evaluation.

On the basis of the feedback obtained from the manager interviews, a preliminary verification was possible of the conceptual validity of the proposed theoretical model, the applicability of the methodology and, finally, the usefulness and usability of both the method and the software.

The risk factors identified through a literature review were verified in the project. All the managers agreed with the presented model during the analysis of the risk factors and their links. This evidence supports the validity of the theoretical model (concerning identification of risk factors) and confirms that is well-grounded in real situations (which also supports the model's applicability). The usefulness and usability of the ISM methodology and associated software were also confirmed by all the managers, who expressed particular appreciation of the benefits it afforded in the early project assessment stage in discussing the risk factors and arriving at a better understanding of the project's complexity.

While our aim in carrying out this study is to make a broad, generalizable methodological contribution to Risk Analysis in ERP projects, the research application is restricted to a single case study. Although a model of the relationships existing amongst ERP project risks has been developed through ISM, it has not been statistically validated, and the information obtained is therefore difficult to generalize. However, the case study does reveal the possibilities offered by applying ISM techniques to the Risk Analysis stage, and its inherent limitations provide clear indications for future work. This is, for example, to include a critical study on several example cases and other relevant empirical investigation. As a future extension of this work, we also plan to apply Structural Equation Modeling (SEM) techniques to statistically corroborate the findings from the ISM model.

As stated in the research objectives, as this study focuses mainly on modeling the interdependence amongst risk factors, risk effects were disregarded in the case study. This represents another limitation of the ERP fault path developed. In future study, risk effects will be included in the ISM analysis, so that their impact and interrelationships can be taken into account. Lastly, the expert opinions used to draw up the interrelationships may lead to some bias in the Risk Analysis process.

Further enhancements will focus firstly on thorough validation of the methodology, then on integrating ISM outputs (including risk effects) into the Risk Evaluation stage, and finally their inclusion in a formal ERP Risk Management tool. Another important aspect concerns final validation and refinement of the method. In this regard, Action Research seems to be a promising approach, since it is well suited to the aims of providing an effective, practical means to improve the development and testing such methodologies.

Appendix A

See Appendix Tables A1 and A2 below.

Table A1
Risk factors dependencies matrix.

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19
R1	Inadequate ERP selection																			
R2	Poor project team skills																			
R3	Low top management involvement																			
R4	Ineffective communication system																			
R5	Low key user involvement																			
R6	Inadequate training and instruction																			
R7	Complex architecture and high number of implementation modules																			
R8	Inadequate BPR																			
R9	Bad managerial conduction																			
R10	Ineffective project management techniques																			
R11	Inadequate change management																			
R12	Inadequate legacy system management																			
R13	Ineffective consulting services experiences																			
R14	Poor leadership																			
R15	Inadequate IT system issues																			
R16	Inadequate IT system maintainability																			
R17	Inadequate IT Supplier stability and performances																			
R18	Ineffective strategic thinking and planning Strategic																			
R19	Inadequate financial management																			

Table A2
Risk factors/effects matrix.

	Budged exceed E1	Time exceed E2	Project stop E3	Poor business performances E4	Inadequate system reliability and stability E5	Low organizational process fitting E6	Low user friendliness E7	Low degree of integration and flexibility E8	Low strategic goals fitting and bad financial/economic performances E9	Bad financial/ economic performance E10
R1 Inadequate ERP selection										
R2 Poor project team skills										
R3 Low top management involvement										
R4 Ineffective communication system										
R5 Low key user involvement										
R6 Inadequate training and instruction										
R7 Complex architecture and high number of implementation modules										
R8 Inadequate BPR										
R9 Bad managerial conduction										
R10 Ineffective project management techniques										
R11 Inadequate change management										
R12 Inadequate legacy system management										
R13 Ineffective consulting services experiences										
R14 Poor leadership										
R15 Inadequate IT system issues										
R16 Inadequate IT system maintainability										
R17 Inadequate IT Supplier stability and performances										
R18 Ineffective strategic thinking and planning Strategic										
R19 Inadequate financial management										

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