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The mission of the IJISPM - International Journal of Information Systems and Project Management - is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

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# Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the third number of the eighth volume of IJISPM. In this issue readers will find important contributions on data science analysis, ERP, IT Governance, IoT project implementation, and Project portfolio risk management.

The first article, "MIDST: an enhanced development environment that improves the maintainability of a data science analysis", is authored by Jeffrey S. Saltz , Kevin Crowston, Robert Heckman, and Yatish Hegde. As the authors state, with the increasing ability to generate actionable insight from data, the field of data science has seen significant growth. As more teams develop data science solutions, the analytical code they develop will need to be enhanced in the future, by an existing or a new team member. Thus, the importance of being able to easily maintain and enhance the code required for an analysis will increase. However, to date, there has been minimal research on the maintainability of an analysis done by a data science team. To help address this gap, in this article the data science maintainability was explored by (1) creating a data science maintainability model, (2) creating a new tool, called MIDST (Modular Interactive Data Science Tool), and then (3) conducting a mixed method experiment to evaluate MIDST. The new tool aims to improve the ability of a team member to update and rerun an existing data science analysis by providing a visual data flow view of the analysis within an integrated code and computational environment.

The title of the second article is "'How IT Governance can assist IoT project implementation", which is authored by David Henriques, Ruben Pereira, Isaías S. Bianchi, Rafael Almeida, and Miguel Mira da Silva. Internet of things (IoT) is considered a key technology for the Industry 4.0 revolution. Information Technology (IT) governance (ITG) is now an increasingly important tool for organizations to align their IT strategy and infrastructures with the organizations' business objectives. The most adopted ITG framework is COBIT, which defines seven enabler categories. These enablers aim to facilitate the implementation, identification, and management of IT. This research aims to determine, explore, and define which are the most suitable IT governance enablers to assist managers in IoT implementation. Results indicate that data privacy, data protection, and data analysis are currently the most relevant enablers to consider in an IoT implementation because they increase the efficiency of the solution and enhance data credibility.

The third article, authored by Moutaz Haddara and Angelo Constantini, is entitled "Fused or Unfused? The Parable of ERP II". One of the major visions is having one system that covers all business functions and satisfies virtually all the standard processes and routine transactions within organizations. In the last decade, several academics and practitioners have predicted the rise of what is called enterprise resource planning systems II (ERP II). ERP II was sought to be a digital platform that is capable of supporting timely decision-making through covering all business functions' processes through having preloaded modules that will minimize the need for external systems like separate customer relationship management (CRM), e-business platforms, and supply chain management (SCM) systems, among others. While ERP systems nowadays have matured, and several packages come with CRM modules and other solutions, however separate CRM systems are still widely adopted by organizations. Thus, this study investigates why organizations that currently have ERPs with CRM modules are still investing in separate CRM systems. The results show that the current ERP systems did not reach the ERP II state as envisioned, as most organizations are inclined to adopt separate CRM systems. The authors have presented five main reasons for this inclination, which are: scoping during ERP implementations, costs, features and functionalities, user-friendliness and ease of use, and finally integration with e-business platforms.

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“Project portfolio risk management: a structured literature review with future directions for research” is the fourth article and is authored by Camilo Micán, Gabriela Fernandes, and Madalena Araújo. Project Portfolio Risk Management (PPRM) has been identified as a relevant area regarding project portfolio success. This paper reports on a structured literature review of PPRM. The content analysis reveals four main recurrent topics in PPRM: (1) The influence of RM on project portfolio success, based on project portfolio impact level, moderators or contingency factors between RM and project portfolio success, and PPRM dimensions; (2) risk and project interdependencies, highlighting resources, technology, outcome, value, and accomplishment project interdependencies; (3) project portfolio risk (PPR) identification, where four main risk source categories are identified; and (4) PPR assessment, composed of risk measures and the main methods used for risk assessment. This study also provides an overview of PPRM as a research field, while it also promotes four future research directions: (1) PPRM as part of organizational RM; (2) RM, success dimensions and strategic impact; (3) mechanisms for PPR assessment, and (4) PPRM as a complex and dynamic system.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Editor-in-Chief,

João Varajão

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João Varajão is currently a professor of information systems and project management at the *University of Minho*. He is also a researcher at the *ALGORITMI Research Center* at the *University of Minho*. Born and raised in Portugal, he attended the *University of Minho*, earning his Undergraduate (1995), Masters (1997), and Doctorate (2003) degrees in Technologies and Information Systems. In 2012, he received his Habilitation degree from the *University of Trás-os-Montes e Alto Douro*. His current main research interests are related to Information Systems and Information Systems Project Management success. Before joining academia, he worked as an IT/IS consultant, project manager, information systems analyst and software developer, for private companies and public institutions. He has supervised more than 100 Masters and Doctoral dissertations in the Information Systems field. He has published over 300 works, including refereed publications, authored books, edited books, as well as book chapters and communications at international conferences. He serves as editor-in-chief, associate editor and member of the editorial board for international journals and has served on numerous committees of international conferences and workshops. He is the co-founder of CENTERIS – Conference on ENTERprise Information Systems and of ProjMAN – International Conference on Project MANagement.

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# MIDST: an enhanced development environment that improves the maintainability of a data science analysis

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**Abstract:**
With the increasing ability to generate actionable insight from data, the field of data science has seen significant growth. As more teams develop data science solutions, the analytical code they develop will need to be enhanced in the future, by an existing or a new team member. Thus, the importance of being able to easily maintain and enhance the code required for an analysis will increase. However, to date, there has been minimal research on the maintainability of an analysis done by a data science team. To help address this gap, data science maintainability was explored by (1) creating a data science maintainability model, (2) creating a new tool, called MIDST (Modular Interactive Data Science Tool), that aims to improve data science maintainability, and then (3) conducting a mixed method experiment to evaluate MIDST. The new tool aims to improve the ability of a team member to update and rerun an existing data science analysis by providing a visual data flow view of the analysis within an integrated code and computational environment. Via an analysis of the quantitative and qualitative survey results, the experiment found that MIDST does help improve the maintainability of an analysis. Thus, this research demonstrates the importance of enhanced tools to help improve the maintainability of data science projects.

**Keywords:**
project management; data science; maintainability; visual programming; data science development environment.

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## 1. Introduction

Data Science is an emerging discipline that combines expertise across a range of domains, including software development, data management and statistics. Data science projects typically have a goal to identify correlations and causal relationships, classify and predict events, identify patterns and anomalies, and infer probabilities, interest and sentiment [1]. As a new field, much has been written about the development of data science algorithms. Unfortunately, less has been written about other challenges that might be encountered when working as a data scientist [2].

One such challenge that has not yet been extensively explored, but that will grow in importance, is the ability to create an analysis that is easy to maintain and enhance. Maintainability, which is the ease with which a solution can be modified to correct faults, improve performance, enhance capabilities, or adapt to a changed environment [3], is of growing importance due to the fact that not every data science analysis is a “one-off” task, and, as more organizations start to leverage data science, there will be a growing need to update previously developed insights. For example, an analysis might need to be updated due to a change in a data source or to evaluate a new machine-learning algorithm. Moreover, this update might need to be done by a new team member, thereby increasing the importance of having code that is easy to understand by someone that was not part of the original team that developed the initial analysis.

In general, maintenance (or actions taken after the first implementation) is an important aspect of a project’s lifecycle [4] and as well as an important aspect of project management [5]. While project documentation can represent a valuable source of knowledge, it has been noted that the knowledge codified in project documents is typically not re-used in future projects [6]. Hence, project documentation, while helpful, is not sufficient for a team to maintain an application.

With respect to data science, Jagadish et al. [7] describe a workflow where data flows from acquisition, to information extraction and cleaning, then to data integration, and then modeling and analysis. Furthermore, due to the exploratory nature of data science, this workflow typically involves iterative cycles of obtaining, cleaning, profiling, analyzing, and interpreting data [8, 9]. However, RStudio, which is the most commonly used tool for creating an analysis when using the R programming language [10, 11], uses a functional code-based framework, which is similar to many software development interactive development environments (IDEs), in that there are multiple views within the environment, including views of actual source code, the output of recently run commands, and of the variables defined in the current scope of execution.

Due to this non-linear flow within data science, Rule et al. [12] observed that an analysis, written using a linear construct, which is how one creates R code within RStudio, often becomes difficult to navigate and understand. This difficulty in navigation and understandability discourages sharing and reuse. One approach that has been explored to address this challenge is the use of a visual data flow metaphor [13], and in fact, a data flow construct has been suggested as the conceptual mental model used by a data scientist [14]. This mental model is very different from the text-based coding environment used within tools such as RStudio. Hence, using tools such as RStudio might create a representation mismatch between the code being written and the abstracted data-driven mental model used by the data scientist [15]. This conceptual mismatch could make it difficult for a data scientist to understand and update code that was previously developed, especially if that code was developed by a different person.

Currently, there is no commonly used general purpose R development environment that is based on the concept of a visual data flow metaphor that defines and links R modules. Thus, one potential step forward to improve the maintainability of an analysis could be via a tool that creates such a visual data flow paradigm, integrated within a code-based programming environment. With this background in mind, our research explored if the maintainability of an analysis could be improved when data scientists use an enhanced development environment. Specifically, we focused on the following research question:

> *Does using visual data flow tool, within an integrated data science development environment, improve the ability of a new team member to reuse and update an existing analysis?*

The next section provides some additional background context. In Section 3, we describe the new tool that was developed to explore our research question, and the methodology used for an experiment to assess the impact of the tool on the maintainability of an analysis. Section 4 presents findings from the study. Section 5 presents a synthesis of our research results, and Section 6 summarizes the research, discusses limitations, and describes possible next steps.

## 2. Background

### *2.1 Data Science Project Maintainability*

Pimentel et al. [16] noted that data science analyses often use poor coding practices, which means that their results can be hard to reproduce and maintain. For example, prior research has revealed that many analyses were difficult to understand, and that even the original analyst can struggle to understand their prior effort [12, 17]. Furthermore, while describing the challenge of creating maintainable R applications, Malviya et al. [18] state that a well-defined workflow (i.e., where to put/get data and how to produce, collect and report the results) can help improve maintainability. They hypothesize that this workflow should be created within a tool, but only describe the tool at a high level. In support of this view, Simmons et al. [19] analyzed code from 1048 data science projects and observed that data science projects suffer from a high rate of functions that use an excessive number of parameters and local variables, and thus, would be difficult to maintain. It was also noted that data science projects do not follow traditional software engineering conventions because traditional software engineering conventions are inappropriate in the context of data science projects.

To help try and address this maintainability challenge, one recent study explored the ability to fold (i.e., hide) logical chunks of code, which had mixed results due to, for example, new data scientists overlooking folded sections [12]. Others have explored how to best capture previous exploration within an analysis by improving tools to understand the history of the analysis [20].

Beyond this, research on data science maintainability is rare [21]. Others have, however, noted the importance in maintaining an analysis. For example, Dhar & Mazumdar [22] identify maintainability as a key challenge in using big data science within an enterprise context and note that the availability of new tools and IDEs could minimize this challenge and make maintenance less of an issue. In addition, Sachdeva & Chung [23] also observe that maintainability is a key challenge that is typically ignored, but which is becoming increasingly important and needs to be handled in a well-defined manner.

Finally, one key aspect of maintainability is reproducibility, which Tatman et al. [24] define as "recreating the exact results" (pg. 2). In other words, it is the extent to which consistent results are obtained when an analysis is repeated. This is an important first step with respect to maintainability because if one cannot reproduce an analysis, then one cannot refine/enhance that analysis. Tatman at al. [24] describe three levels of reproducibility. Low reproducibility studies are those which merely describe algorithms that were used within an analysis, medium reproducibility studies are those which provide the code and data but not the computational environment in which the code can be run, and high reproducibility studies are those which provide the code, data, and full computational environment necessary to reproduce the results of the study.

With respect to reproducibility, it has been noted that high reproducibility is a significant challenge when developing R-based analyses [25]. In fact, Beaulieu-Jones & Greene [26] observed that even an analysis that is "scriptable and should be easy to reproduce (...) remains difficult and time consuming to reproduce computational results because analyses are designed and run in a specific computing environment, which may be difficult or impossible to match from written instructions" (pg. 342).

### *2.2 Data Science Development Environments*

Beyond RStudio, there are other development environments that focus on high reproducibility, such as container-based environments. Specifically, high reproducibility can be achieved via the use of a container tool such as docker, which allows an application to be packaged with all its parts, such as libraries and other dependencies, and act like a light weight virtual machine for creating a complete computing environment [25, 26]. This includes tools such as Kaggle Kernels [27] and Jupyter notebooks [28]. However, none of these environments address the non-linear nature of data science analysis [12].

As previously noted, a visual data flow metaphor might be an interesting alternative to existing data science IDEs. At its core, a visual data flow program represents code using graphical box-and-wire diagrams, where boxes denote modules (or functions) and wires denote the passing of values between functions [27]. Leveraging this visual data flow paradigm has been used for decades to analyze data [29, 30]. For example, the Application Visualization System (AVS) was created nearly thirty years ago [31] and was designed around the concept of software building blocks, or modules, which could be interconnected to form a visual data flow program. In fact, it has been noted that visual data flow programming is most successful where data manipulation is the foremost important task [32].

This visual metaphor is now receiving renewed attention across a range of applications [33, 34]. However, within a data science context, these visual data science data flow tools do not focus on the development of R code. Rather, these are higher-level tools that promote the idea of "machine learning for everyone" by enabling people who do not code to be able to create a data analysis. For example, Weka [35], a popular machine learning development environment, provides both a command line interface and a graphical interface that is focused on higher-level graphical programming, as opposed to providing a graphical user interface to help data scientists develop their R code. Another visual data science tool, KNIME, does make it possible for programmers to create nodes using a node wrapper that understands/parses R code, but like Weka, developing new R code is not core to the thought process of the users of KNIME [36]. Other examples of these higher-level visual programming environments include ViSta for statistical analysis [37], and Orange for machine learning [38]. In other words, while there are visual data flow programming tools for data science, these tools are focused on higher level constructs to create an analysis by reusing existing nodes or whole workflows (i.e., not focused on programming). Due to this difference in focus, it has been observed that when trying to develop R code within tools such as KNIME, users had issues due to the lack of integration between visual data flow editor and the textual environment, which led to user frustration [39].

In short, there is currently no commonly used general purpose development environment for developing R code that is based on the concept of data flow, where the user creates code modules and links those custom nodes [39]. However, a small 4-person case study of a data flow prototype system found that integrating a code-based environment with a visual data flow view was useful in creating a more understandable analysis [40], which suggests that a visual data flow view might improve maintainability.

### *2.3 Software Development Project Maintainability Models*

Even in software development, the concept of maintainability is often overlooked. For example, in a systematic literature review that focused on compiling and synthesizing project success factors in Information Technology (IT) projects, the concept of maintainability was not explicitly noted [41]. Furthermore, the need for maintainability was only implicitly noted in a systematic literature review that identified factors of IT project complexity, where reusability was noted as a key complexity factor [42].

However, due to the importance of software maintainability, during the past 20+ years, a wide range of maintainability models have been proposed. In one model, Muthanna et al. [43] focused on design level metrics that characterize the overall data and control flow between modules. In a different example, [44] describes a higher-level quality model, which includes self-descriptiveness, modifiability and testability as the sub characteristics for maintainability. In yet a different example, Rizvi et al. [45] describe a model for maintainability that has two key factors: understandability and modifiability. More generally, Dubey & Rana [46] analyzed 17 maintainability models and identified 37 different maintainability attributes. The most frequently mentioned attribute was testability (noted in 47% of the models), and other frequently mentioned attributes included self-descriptiveness, modifiability and understandability. In fact, understandability has been identified as playing a pivotal role in software maintenance [47].

With respect to evaluating the maintainability of a software system, Roehm et al. [48] explored maintainability via an observational study of 28 developers to identify the steps developers perform when understanding software and the artifacts they investigate. A different approach was used by Shima et al. [49], where they assessed the ability of students, acting as a proxy for developers, to correctly reconstruct a system from its components, which they termed "software overhaul".

### *2.4 Deriving a Data Science Maintainability Model*

Our data science maintainability model is shown in Figure 1. Since many, such as Schneberger [50], noted the importance of a development environment, this is the initial factor within the model. Furthermore, while testability was a key concept within a software development context, we leveraged Tatman et al.'s [24] concept of reproducibility as a related, but more relevant factor for data science analysis. So, in parallel with reproducibility, we also introduced understandability as a key factor to enable maintainability. Thus, within our model, the maintainability of an analysis is driven by being able to understand and recreate the analysis, both of which could be facilitated via the use of an enhanced development environment. Note that we broadly define a development environment to include the tools used to create, update, run and share an analysis.

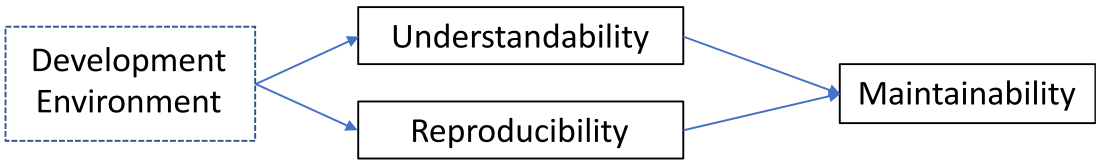


Fig. 1. Data Science Maintainability Model

## 3. Methodology

### *3.1 Research Method*

To explore how to improve data science analysis maintainability, we used our data science maintainability model, which was previously shown in Figure 1. First, we developed a new visual data flow data science development environment, called MIDST (Modular Interactive Data Science Tool), that we hypothesized would improve understandability and reproducibility. Then, to compare the maintainability of an analysis done using RStudio to an analysis done using the new visual data flow tool, we measured the reproducibility and understandability of an analysis done using RStudio with an analysis done using MIDST.

In short, to evaluate reproducibility and understandability, we leveraged the previously discussed methodological concept of a software overhaul [49], but adapted the software overhaul concept to a data science context by having the data scientist share an analysis with a person not involved with its development, and then having that other person update and re-run that existing analysis. Specifically, we conducted an experiment where, in the baseline condition, the analysis and updates were done using RStudio, and in the other, experimental condition, teams used MIDST's new visual development environment. All teams, across both conditions, analyzed the same data, and the new person was given the same task in terms of updating the analysis.

The rest of this section describes our research method in more depth.

### *3.2 New Visual Data Flow Environment - MIDST*

MIDST is a web-based data science IDE that was developed for this project. Due to MIDST's web-based architecture, all the R code runs on a common compute server. This shared execution environment greatly facilitates team collaboration since issues such as what libraries and what versions are installed as well as other details such as location of data files are eliminated. As well, it makes it easy to share code between team members.

When using MIDST, all members of a team can share their code via an easy to use graphical code management system that lets each team member easily “push” their updates and “pull” updates from the team’s shared repository, which integrates all modules used in the team’s analysis. In fact, MIDST has reminders when a team member needs to pull the updates from their shared repository. In addition, MIDST provides a common computing infrastructure, where each user has a clone of the same computing environment. MIDST provides several different views to enable data scientists to leverage visual data flow programming to construct an analysis.

*MIDST Network View*: MIDST’s network view provides the high-level data flow view of the modules within the application. This network view, shown in Figure 2, enables users to create nodes, define the input and output for each node, and then connect those nodes together, via the concept of data flowing between the nodes. In addition to code modules (the R code is within each of the code modules of the network), there are data nodes and output visualization nodes. Similar to other data flow systems, each code module node within MIDST has inputs and outputs, and MIDST users connect the nodes, where the output of one node is the input to another node. For example, Figure 2 shows a simple application that reads in a raw data file, cleans the data file, stores that data file and then generate a histogram.

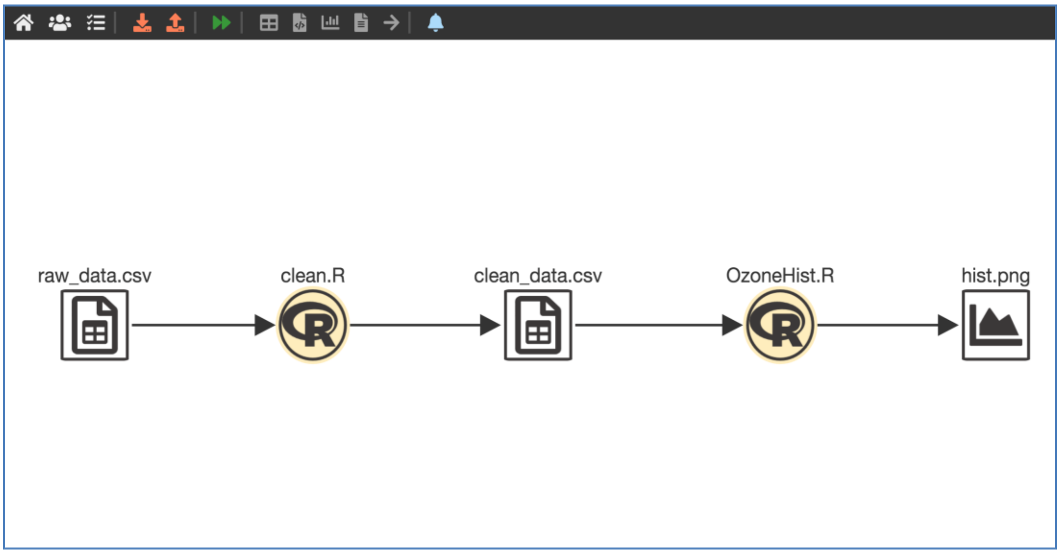


Fig. 2. MIDST Network View

As with other data flow tools, the network editor helps users break tasks into chunks, and to visualize the flow of the project. Of course, since the user has control over how to define the network and the inputs and outputs of each node, the simple analysis shown in Figure 2 could be implemented via a different data flow diagram, as shown in Figure 3.

Within this network view, MIDST users can easily execute the entire network (within their cloned virtual environment) by pressing the ‘run’ button at the top of their network view window, and any errors that occur during execution of the network are clearly visible as failed nodes, as shown via the exclamation mark in Figure 4. The current version of MIDST does not provide a library of previously created nodes/modules that were used in previous projects or created as utility modules by others. A more production-oriented version of MIDST could easily provide such a library of modules.

*MIDST Source Code Editor*: MIDST also allows users to drill down to the actual R code within a module, by clicking on a node to view/edit the actual R code within the MIDST source code editor, which is similar to the editor in RStudio. The code view is more of a typical source code editor, with the ability to view, edit and run the actual R code for each of the modules within the application. As shown in Figure 5, the editor enables the user to write and debug the R code for a module. For example, the R code for the clean module from Figure 3 is shown in Figure 5. In this view, similar to how one uses RStudio, the user writes R code to implement the required functionality for that module. Also, within the source code editor, one can either run the entire module or execute a line of code in the module. Output for the module is always shown in the bottom window pane of the source code editor. This output is for the most recent run of the module (whether that was due to the full network being run in the network view, the full module being run in the source code editor view, or a specific line being executed within the source code editor).

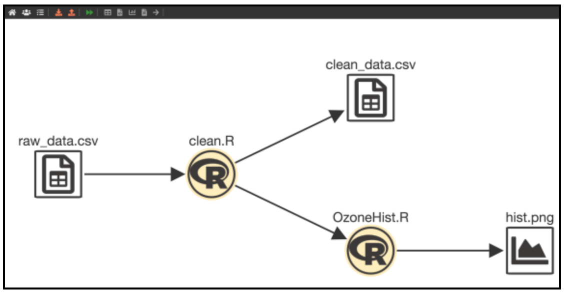


Fig. 3. Alternative MIDST Network

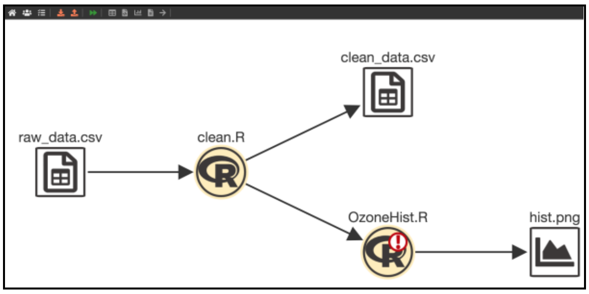


Fig 4. MIDST Network View – with an error

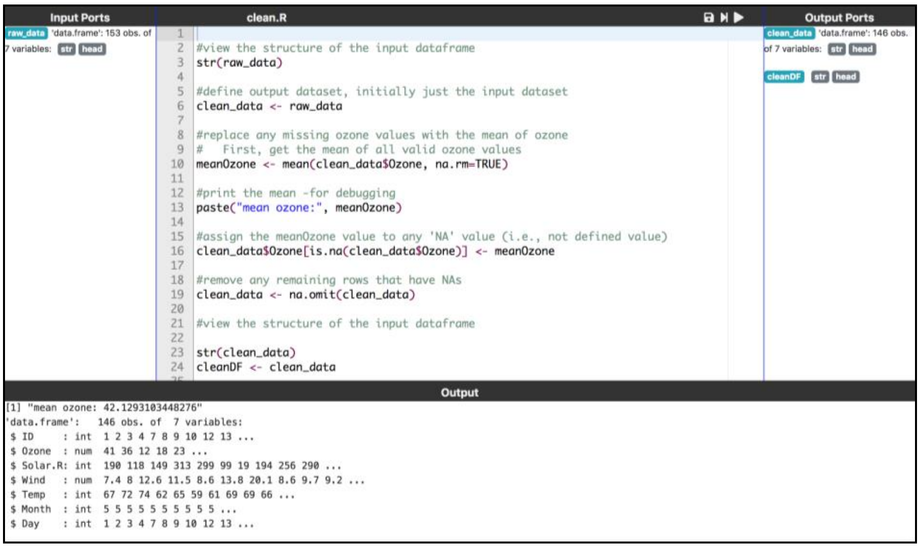


Fig. 5. MIDST Source Code Editor

### *3.3 Maintainability Experiment*

To evaluate the impact of MIDST, a mixed method experiment was conducted where the experimental condition, of participants using MIDST, was compared to the baseline condition, of participants using RStudio.

Participants in both conditions were assigned the same initial task, which was an eight-week long group project, where teams of 4-6 people analyzed a customer survey dataset. The analysis included typical data science tasks such as using visualization, mapping techniques, and machine learning to predict unhappy customers. After the analysis was completed (and submitted for evaluation), there was an optional extra task. For this voluntary task, participants shared their project with a person in a different team (but within the same experimental condition), and then that new person updated the analysis. The update consisted of the simple task of sampling 75% of the data, after cleaning, and then comparing the results the analysis using the sampled dataset with the evaluation that was conducted when using the entire dataset.

During the experiment, for both the baseline (RStudio) and treatment (MIDST) conditions, quantitative and qualitative information was collected. Table 1 shows the quantitative data collected, which was used to measure reproducibility and understandability. Specifically, we considered two sharing metrics to be indicators of reproducibility: the time it took to locate and assemble the original code, and the percentage of the original code that was shared. The percentage of the original analysis that was able to be run correctly is a third indicator of reproducibility. The time necessary to update the analysis is an indicator of understandability. The time metrics are similar to those used in a software development context, where the maintainability of a system was explored by measuring the total effort, in person-minutes, to comprehend, modify, and test the artifacts related to the system [51].

Table 1. Metrics collected and map from actions to testability and modifiability

| **Action** | **Metrics** | **How Measured** | **Relevance:** Reproducibility | **Relevance:** Understandability |
|---|---|---|---|---|
| Share Analysis | Time to Share Analysis | Self-reported by person sharing the analysis | X | |
| | Percentage of Analysis Shared | Objective assessment | X | |
| Run Analysis | Percentage of Analysis run correctly | Objective assessment | X | |
| Update Analysis | Time to modify analysis | Self-reported by person doing the updates | | X |

With respect to the qualitative data, to better understand the thoughts and perceptions of doing this assignment, participants were asked, via an online survey, the following open-ended questions:

- “What were the key challenges to get the code running?”
- “What challenges did you encounter when you tried to update the other team's code?”
- “Please provide some general thoughts/impressions of doing this assignment.”

### *3.4 Data Evaluation*

For the quantitative data, the percentage of code shared as well as the percentage of the analysis that was able to be run correctly was determined via an analysis of the code performed by a teaching assistant for the class, who was not part of this research effort. The participants also reported on the time it took them to share their team’s analysis, as well as the time it took them to modify the analysis the analysis that they were given to update.

The qualitative data was analyzed to identify the key themes with respect to sharing, updating and running the analysis. This thematic analysis was performed for the comments in the MIDST condition and another thematic analysis was performed for students in the baseline condition. Specifically, for each condition, the Miles and Huberman approach to analytic induction was used [52], with a goal of identifying common themes via an iterative process of item surfacing, refinement and regrouping. The coding started by reviewing each response and defining a high-level item description. If needed, one response was broken into multiple items. These item descriptions were then grouped and re-grouped into higher level conceptual themes. To increase reliability, the coding was done independently by two researchers [53], and ambiguities in coding were discussed and resolved amongst the researchers.

### *3.5 Experimental Conditions*

The participants in this study were graduate students. In terms of the appropriateness of using graduate students within the study, while there has been little written about using students to gain insight into industry teams within a data science context, student experiments within the software development domain have been taking place for decades. In fact, students were used as subjects in 87% of the experiments analyzed over a representative ten-year period [54]. It is also important to note that when using students as subjects, several factors are typically considered. First, “students vs. professionals” is actually a misrepresentation of the confounding effect of proficiency, and in fact differences in performance are much more important than differences in status [55]. Hence, using master level students, many of whom have several years of industry experience can often be a more appropriate choice than undergraduate students with minimal experience. Second, comparing across experimental conditions, using students may actually reduce variability because all students have about the same level of education, leading to better statistical characteristics [56]. Finally, a third consideration is that while students might not be as experienced as practicing professionals, they can be viewed as the next generation of professionals and hence many believe they are suitable subjects for these types of studies [57, 58].

In total, ninety-six graduate students participated in our study. While most of the students in each section were graduate information system students, approximately fifteen percent of the students in each section were in other graduate programs, mainly business administration or public policy. Sixty-five percent of the students had previous work experience. In addition, forty percent of the participants were female. Thirty five percent of the participants were from North America, fifty-five percent from Asia, and ten percent from other locations (all students were co-located during the actual experiment).

The students initially registered to be in one of four sections, without any knowledge of which sections would use MIDST, or which sections would not use MIDST. Two of the sections (with a total of 44 students) were selected to be in the baseline (i.e., RStudio) condition, and two of the sections (with a total of 51 students) were in the treatment (i.e., MIDST) condition, where the students used MIDST to do the analysis.

## 4. Findings

In the Baseline (RStudio) sections, 31 students out of 44 chose to do the extra-credit assignment. In the Treatment (MIDST) sections, 13 students out of 52 chose to do the extra credit assignment using MIDST.

We note that there were 19 other students in the MIDST condition who chose to do the voluntary extra credit assignment using RStudio, which was permitted for the voluntary assignment. This was likely due to the fact that MIDST was an early prototype system, and as will be noted in the qualitative findings, there were some issues that students would occasionally encounter. To explore the possibility of selection bias, we observe that the 19 students in the MIDST condition that used RStudio had a final grade average of 86.1% (with a standard deviation of 4.7), and the 13 students that used MIDST for the maintainability task had an average of 87.0% (with a standard deviation of 3.4). Thus, since the focus of our analysis was on comparing the “No MIDST” condition with the “MIDST” condition, and since there was no selection bias (as noted via the final grade averages), we excluded the 19 students that used RStudio but were in the MIDST condition from the analysis. Also note that, during the sharing of the code, one MIDST user found a bug in MIDST and the time reported for this user was heavily influenced by this bug, so this user’s data was not used during the analysis (hence we only evaluated the 12 students that used MIDST and did not encounter this bug).

### *4.1 Sharing the project*

As can be seen in Table 2, students in the MIDST condition shared more of the project (100% vs 84%, on average), and did so much more quickly (30 minutes vs 80 minutes, on average). Using a t-test, which is a statistical test that can be used to determine if there is a significant difference between the means of two groups (in other words, a t-test lets one know if the difference in the mean could have happened by chance), the difference in both what was shared, and how long it took to share the code, was significant.

Table 2. Results for Sharing the Code

| | How the code was shared | | Significant Results |
|---|---|---|---|
| | R Files(s) *(N=31)* | MIDST Network *(N=12)* | *(at p=0.5 level)* |
| Time required to share the code *(average # of minutes)* | 80 | 30 | Yes |
| Percentage of project that was shared (*average*) | 84% | 100% | Yes |

### *4.2 Updating & Running the project*

As can be seen in Table 3, students in the MIDST condition got more of the project code analysis to run correctly (91% vs 78%, on average). It also took them significantly less time to update the code. MIDST users took an average of 3 hours to complete the task, versus close to 5 hours for students working within RStudio. Using a t-test, the differences in how much of the project was able to be successfully recreated, as well as how long it took to do the project update, were both significant. Note that 3 people in the "no MIDST" (RStudio) condition did not finish the project enhancement, and hence, were removed from this part of the analysis.

Table 3. Results for updating the code criteria

| | Updates Done Using | | Significant Results |
|---|---|---|---|
| | RStudio | MIDST | *(at p=0.5 level)* |
| Percentage of code that was working correctly *(percentage of total analysis)* | 78% | 91% | Yes |
| Time needed to make changes (*average # of minutes*) | 299 | 180 | Yes |

### *4.3 Qualitative Feedback*

Our thematic analysis of the qualitative data (i.e., the free form participant survey questions), provides some context as to the challenges RStudio students encountered when sharing and updating the project. Specifically, three key themes were identified for the baseline (RStudio) condition, all related to how difficult the task was to do (i.e., sharing, updating and running the code). In contrast, in the MIDST condition, three different themes emerged (sharing and running the code was easy, and updating the code was easier due to visual data flow network that made the code easier to understand). Below, these themes are explored in more depth.

#### *4.3.1 Baseline Users Qualitative Feedback (RStudio)*

As demonstrated by the example comments below, for each of the identified themes, participants felt that sharing the analysis was difficult because after they divided the work across the team members, the team members did not share their code with the other team members. In other words, each team member typically worked in isolation from each other. Furthermore, many in the baseline condition thought that updating the code was difficult, mainly due to the fact that it was a challenge to understand the flow of the analysis. Finally, running the code in the baseline condition was also difficult, mainly due to not all the code being integrated within a single environment.

*Sharing the code – hard to do*

> "For our project, each group member was responsible for using their own code in creating allocated visualizations, models, etc. So, when attempting to combine it as one code, some things didn't match up. Naming of vectors was different, subsets we defined and used then interfered with later code, there was just a few things that weren't included. For some reason I wasn't able to include the association rules code."

> "Not all of our code was shared with me so I shared as much as I could."

> "Text mining- I did not have the function that was created and used … Hence, instead of sharing an incomplete code, I chose not to include that [part of the analysis]."

> "I did not share a particular code of my group project … the person who did his part … was travelling [and] I did not want the person waiting."

> "Shared the R script file via Email. Sent it as an attachment."

*Updating the code – hard to do*

> "It is too hard to find which part should be modified."

> "The flow of the analysis was a little haywire, with no clear distinctions between linear modelling, descriptive statistics, a-rules and SVM. They were all correct, but it took me a while to understand the flow of the code."

> "What made the project relatively hard to follow and replicate is the fact that there was no cohesion in the work. Given that the folder that I received contained different files representing the various sections of the project, it was not obvious to figure out objects that may change from one section to the other. As such, there was no structure to follow in re-running and updating the project."

> "One of the key challenges was to understand the code. Although there were comments … the code as a whole was little haphazard."

*Running the code – hard to do*

> "Different files used different datasets so it was really difficult to change it."

> "With respect to the R code, I had to update the variables and adjust some codes w.r.t. the sample dataset."

> "I had to change … the variable names so that I could get the code running."

> "About 30% of the code [had to be] changed. I had to correct the syntax errors, changed the map visuals to make them work."

> "[it was difficult] going over the errors and understanding why the errors were happening and also looking at different functions. Every group had their own functions so understanding what different functions do [was challenging]."

"Three of the substantial algorithms failed to run due to missing objects that were not defined and that I couldn't figure out their origin/source."

### *4.3.2 MIDST Users Qualitative Feedback*

Unlike the baseline users, almost all people using MIDST noted that sharing was easy, as was updating the code. However, due to the fact that MIDST was a prototype system, some also noted the MIDST bugs and performance issues.

*Sharing the code – was easy*

"I shared the entire code with the other person through MIDST."

"I shared every single part of our project with the other member."

"Easiest way was to provide the Midst link by adding them as temporary collaborator."

*Updating the code – leveraged the visual data flow network to understand the code*

"It was important to understand the other team's project and the flow of data between all the nodes in order to update the code so as to get the code running without any errors."

"I just needed to add a node with the sampling coded … and then supply this sampling dataset to the models."

"I updated code in a single node…I was able to understand the code due to the flow in MIDST."

"I added a node in the MIDST tool to sample the data. After cleaning, I added the flow to the new node sampling.R. After creating the sampled data set, the data was supplied to the models for analysis."

"The code provided on MIDST was put in an easy to understand fashion. I went through various nodes to understand their function."

*Running the code* - *easy except for MIDST bugs*

"Overall, I did not face any major challenge while running the code."

"The entire project was running properly. The only issue was … a bug in MIDST, which resulted in errors but after running the network again, the entire network ran without any errors."

"There were some errors shown on MIDST, but after running the code node by node, the errors were fixed."

"My code was in MIDST and I was able to easily run all my modules at one time. The only problem I had was while editing the code, there was an error message popping and it was taking too long to execute whereas the same code was running fast in R."

## 5. Discussion

By leveraging our maintainability model, it can be noted that MIDST improved the both the reproducibility and understandability of an analysis, and thus improved the maintainability of that analysis. Specifically, as shown in Figure 6, there are two key features, which are discussed below, that enabled this improvement. The two features are that (1) MIDST provides a complete, integrated code and execution environment, and that (2) MIDST provides a visual data flow view of the analysis that augments the code-based view of the analysis.

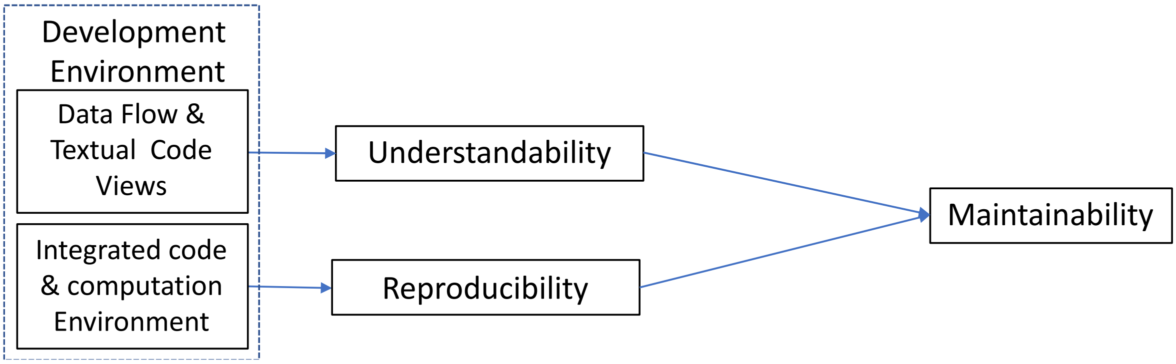


Fig. 6. Key Features of a development environment that leads to improved maintainability

### *5.1 MIDST's Integrated code and execution environment*

One key feature of MIDST is that it provides the code, data, and full computational environment within an integrated environment. Our results show that this integrated environment improved the reproducibility of an analysis by enabling more of the code to be shared, in less time. It also helped enable more of the code (i.e., the analysis) to be executed by a new person.

Some teams in the "No MIDST" condition tried to mitigate this issue (of not having an integrated environment) by having each team member work on a specific analysis. Then, the results of the different analyses were "merged" via a high-level report (i.e., the final report was a collection of non-integrated efforts and the code was not merged into a shared repository/code base). Unfortunately, this approach created maintainability problems because others on the team could not easily understand or run the full analysis. An integrated code repository, such as Github [59], only partially solves this issue in that different team members might still have different execution environments – for example, different libraries installed or access to different data repositories. Hence, an integrated environment is necessary "in order to avoid the 'it runs on my machine' problem, where a project can only be reproduced by running it on the same computer it was originally written on" [24]. This problem is why it has been noted that sharing code and data is an important first step to improve reproducibility, but having a cloned computational environment "increases the ease and longevity of reproducible research projects" [24].

### *5.2 MIDST's visual data flow dataflow metaphor*

MIDST's visual data flow metaphor might have improved the understandability of an analysis due to the fact that the visual data flow view mapped to a data scientists' mental model. With this in mind, we believe that MIDST creates an easier to understand analysis. Several participants noticed MIDST's ability to help improve the understanding the entire project, including comments such as:

> "It was important to understand the other team's project and the flow of data between all the nodes in order to update the code so as to get the code running without any errors."

> "I was able to understand the code due to the flow in MIDST."

"The code provided on MIDST was put in an easy to understand fashion. I went through various nodes to understand their function. Overall, I did not face any major challenge while running the code."

## 6. Conclusion

### *6.1 Summary*

This study defined and then used a new data science maintainability model, which is based on understandability and reproducibility. The study then used the model to evaluate a new data science interactive development environment (MIDST), which provides an integrated code and execution environment as well as a visual data flow of the analysis, was described and analyzed.

Specifically, to address our research question (*Does using visual data flow tool, within an integrated data science development environment, improve the ability of a new team member to reuse and update an existing analysis?),* a mixed method research study comparing the maintainability of an analysis developed in MIDST compared to an analysis developed within RStudio was performed.

The results of the study did answer the research question, in that the study demonstrated that using visual data flow tool does improve the ability of a new team member to reuse and update an existing analysis. In short, this research shows that a visual data flow tool, such as MIDST, improves the reproducibility and understandability of a data science analysis. Hence, the study highlights the need to explore the development of additional code-level visual data flow IDEs, to complement existing higher-level visual data flow IDEs that currently target higher-level end users who do not need to develop code.

### *6.2 Limitations and Next Steps*

Based on our newly defined data science maintainability model, this study suggests that an analysis is easier to maintain when using MIDST. Future research should leverage these results to continue to explore how tools and processes could improve the maintainability of a data science analysis. Future research could also explore MIDST within an industry context.

One limitation of this research was that some of the findings, with respect to how long tasks took, were self-reported. Future research could explore different approaches to measure how long a task takes to complete, such as providing a fixed amount of time to update an analysis within a controlled environment, similar to what was done by Rule et al. [12]. Further refinements of the Maintainability Model could also be explored, such as whether there are alternative ways to operationalize the reproducibility and understandability variables. In addition, the bugs and performance issues within MIDST might have reduced the impact of the visual data flow approach. Hence, work will continue on improving the robustness and usability of MIDST.

Another possible next step is to note that another alternative to code-based programming environments, such as notebooks, which as previously noted, enables one to integrate R code, R output and formatted textual explanations of the analysis within one document. However, since notebooks do not naturally enable one to easily keep track of the output from one step (such as data cleaning) that is to be used across multiple next steps (such as different data analytical algorithms or visualizations), future research could explore the use of notebooks within a data flow context.

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# How IT Governance can assist IoT project implementation

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**Abstract:**
Internet of things (IoT) is considered a key technology for the Industry 4.0 revolution. Information Technology (IT) governance (ITG) is now an increasingly important tool for organizations to align their IT strategy and infrastructures with the organizations' business objectives. The most adopted ITG framework is COBIT, which defines seven enabler categories. These enablers aim to facilitate the implementation, identification, and management of IT. This research aims to determine, explore, and define which are the most suitable IT governance enablers to assist managers in IoT implementation. The study adopted the Design Science Research methodology, including two systematic literature reviews and a Delphi method to build the artefact. The artefact was demonstrated and evaluated in a real organization. The results indicate that data privacy, data protection, and data analysis are currently the most relevant enablers to consider in an IoT implementation because they increase the efficiency of the solution and enhance data credibility.

**Keywords:**
IT governance; IoT; enablers; COBIT; Design Science Research; Delphi method.

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## 1. Introduction

Information Technology (IT) is one of the pillars of our society, changing the way people relate to each other and how businesses communicate and interact among them [1]. IT has become an essential asset in operations and business growth; organizations are becoming completely dependent on it, which has led them to shift their attention to IT governance (ITG) [2][4].

ITG has been demanded by many organizations [5] to ensure that IT is aligned with business objectives [6] and creates value to the business [7]. Measuring IT performance and competitive advantages delivered by IT within the organization as well as align IT objectives with the overall business strategy are among the main goals of ITG [8]–[10]. Plus, ITG formalizes IT accountability to ensure more effectiveness and ethical management within the organization [11][7].

Grounded on the critical role of IT for business success, some ITG frameworks have been developed to guide and assist ITG implementation. One of the most known is COBIT [12], developed by the Information Technology Governance Institute of the Information Systems Audit and Control Association (ISACA) [13]. It defines COBIT as the framework for governing and managing IT in a holistic manner in all organizations [14]. Contributions of COBIT to organizations were studied before [15]. COBIT 2019 defines a set of enablers to support the implementation of an ITG system within an organizations' IT [14]. Enablers have the intention of allowing organizations to manage their complex interactions and facilitate successful outcomes [16]. ITG has been used to govern different kinds of technologies including emergent technologies applied in smart cities [17]–[19].

This is even more critical when an organization wants to adopt novel technologies to win competitive advantage. In turn, IoT was considered as the next wave of innovation by the industry leaders [12] and is becoming very popular in the context of the IT revolution that most are now facing [20]. According to a McKinsey report [21], there will be at least 30 million IoT devices connected and interacting by 2020. Given the ability to create better systems of knowledge-based decision systems [22], IoT is considered an important strategic technology trend that will shape business opportunities and competitive advantage [23]. However, it needs to be well integrated, managed, and governed to potentiate its benefits [24][25]. So far, no studies have been aimed at investigating ITG issues regarding IoT projects. Therefore, this research aims to investigate which are the main ITG enablers to help organizations implement IoT. Two systematic literature reviews (SLR) were performed to systematize ITG enabler definitions and define the former list of ITG enablers for IoT. Then, a Delphi study with three rounds was performed with 7 IoT experts. Lastly, the final list of ITG enablers was assessed in a very experienced organization regarding IoT projects.

## 2. Research Methodology

This research follows the design science research (DSR) methodology. It includes two SLRs and a Delphi method to find out a set of enablers that were afterwards validated via interviews to reach our artefact. In Figure 1 one may understand how all these techniques were applied and integrated. The motivation behind DSR is to improve the environment [26], implementing new and innovative artefacts [27] to solve identified organizational problems [28].

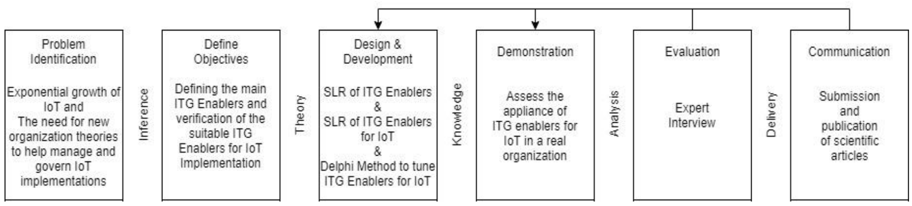


Fig. 1. DSR process model

The first and second phase of DSR are detailed in the Introduction. The remaining phases will be further explained in following sections. We performed two systematic literature reviews and a Delphi research to find out a set of enablers that were afterwards validated with interviews.

### 2.1 *Design and Development*

Grounded on the information presented in Figure 1 regarding the "Design and Development phase", Figure 2 conceptualizes how the several used methods relate to building the final artefact.

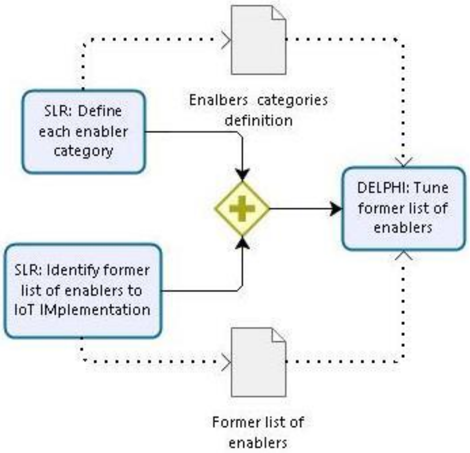


Fig. 2. Design and Development: How the methods relate to build the artefact

### 2.2 *Systematic Literature Review of IT Governance Enablers*

To perform this SLR the authors have followed guidelines proposed by Kitchenham [29]. Figure 3 delineates the methodology steps that were followed, which are further detailed in the next paragraphs.

| Outlining Systematic Literature Review | | Conducting Systematic Literature Review | | Reporting the Reviews |
|---|---|---|---|---|
| **Identification of the need for a review**<br>• Despite identified, a detailed definition of ITG enablers is unknown | | **Applying filters and get final articles**<br>• 31 articles analyzed | | **Report the findings**<br>• Present the definition of the several enablers |
| **Objective of the review**<br>• Define each ITG enabler | → | **Perform Data extraction and analysis of the sample**<br>• Extraction information about enablers definition | → | |
| **Review Protocol**<br>• Search strings, filters, repositories, inclusion/exclusion criteria, quality criteria | | | | |

Fig. 3. ITG enablers SLR stages.

This SLR aimed to better understand the definition of each ITG enabler proposed by COBIT2019. These are Principles, Policies, and Frameworks; Processes; Culture, Ethics, and Behavior; Services, Infrastructure, and Applications; People, Skills, and Competencies; Organizational Structures; and Information.

The search for this review began on July 12th, 2018 and ended on October 15th, 2018 in the following databases: Google Scholar and Scopus. Data sources were systematically searched using carefully selected search terms or keywords that are presented in Table 1.

Table 1. ITG enablers SLR: Search string and keywords

| Search Category | Keywords |
|---|---|
| ITG | IT governance definition |
| ITG Enablers | IT governance principles, IT governance culture, IT governance ethics, IT governance information, IT governance people, Governance organizational structures, IT governance skills, IT governance competencies, IT governance applications, IT People |
| COBIT Enablers | COBIT processes, COBIT principles, COBIT framework. |

For example, the term ITG is included along with enablers, as they are very complementary to one another. The search was separated by categories ("ITG", "ITG enablers", "COBIT enablers"). Within these categories, several keywords were selected and combined using Boolean "AND", e.g.: between IT governance "AND" principles. Table 2 presents the filtration stages and which filters were used.

The inclusion and exclusion (IE) criteria for this review were guided by the following criteria questions:

- **IE1:** Is the article context related to ITG?
- **IE2:** Is the article related to the research context?
- **IE3:** Do the findings of the article provide valuable insights to define one or more ITG enablers?

Table 2. ITG enablers SLR: Filtration stages

| Filtration Iterations | Description | Assessment criteria | Article Count |
|---|---|---|---|
| 1st filtration | Identification of the relevant studies from the selected databases. | Search Category and keywords using the filter "". | 35559 |
| 2nd filtration | The studies were excluded based on their titles. | Title = Search terms. | 3327 |
| 3rd filtration | The studies were excluded based on their abstracts. | Keywords inside the abstract. | 359 |
| Final filtration | Obtain the most relevant articles. | Address the quality and criteria questions. | 31 |

It is important to point out that this review included only articles published in English with a year range between 1999 to 2018. Furthermore, quality criteria were applied. The authors have selected only articles ranked as Q1/Q2 (from Scimago) or A/B (from ERA) ranking. Overall, 31 articles were selected and analyzed. Following the concept-centric approach [30], Table 3 identifies the analyzed articles for each ITG enabler. Each enabler was then defined and its description used in the Delphi phase. For space limitations, the complete definition of each enabler is not presented.

Table 3. ITG enablers SLR: Final list and references

| ITG enablers | References | Total |
|---|---|---|
| Principles, Policies, and Frameworks | [12], [13], [31]–[43] | 14 |
| Processes | [32], [39], [40], [42], [44]–[47] | 8 |
| Culture, Ethics, and Behavior | [39], [42], [43], [46]–[50] | 8 |
| Services, Infrastructure, and Applications | [33], [36], [39], [51]–[53] | 7 |
| People, Skills, and Competencies | [39], [40], [50], [54]–[57] | 7 |
| Organizational Structures | [5], [39], [42], [46], [47] | 5 |
| Information | [39], [42], [50], [58] | 4 |

### *2.3 Systematic Literature Review of IT Governance Enablers for IoT*

To perform this SLR the authors have followed guidelines proposed by Kitchenham [29]. Figure 4 presents the methodology steps that were adhered to and are further detailed in the next paragraphs.

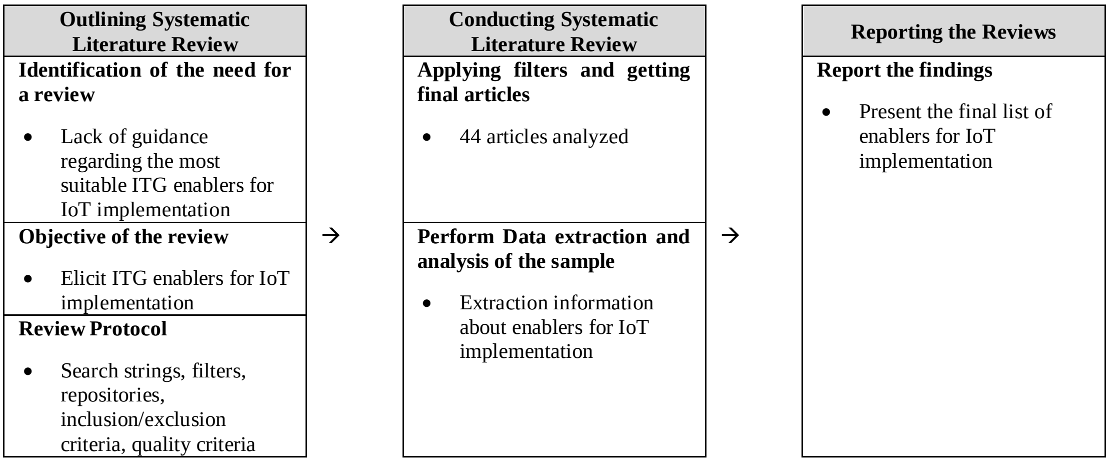


Fig. 4. ITG enablers for IoT implementation SLR stages.

The search for this review began on October 20th, 2018 and finished on December 23rd, 2018 in the following databases: Google Scholar, Taylor & Francis and Scopus. Google Scholar and Scopus are two brokers from which we captured nearly all the articles. During the second SLR we decided to further reinforce our review and chose to include Taylor DB. We could have chosen IEEE or ACM, but these DBs tend to be more technical; we believed that Taylor could be more productive to obtain proper articles. The data sources were systematically examined using carefully selected search terms or keywords (Table 4). Table 5 presents the filtration stages and which filters were used in this search.

Table 4. ITG enablers SLR for IoT: Search string and keywords

| Search Category | Keywords |
|---|---|
| IoT | IoT definition, IoT adoption |
| IoT Enablers | IoT principles, IoT adoption principles, IoT frameworks, IoT frameworks standards, IoT policies, IoT processes, IoT processes governance, IoT processes cobit, IoT organizational structures, IoT structures, IoT culture, IoT ethics, IoT behavior, IoT information, IoT services, IoT infrastructures, IoT applications governance, IoT people, IoT people roles, IoT people responsibilities, IoT skills, IoT competencies |

Table 5. ITG enablers SLR for IoT: Filtration stages

| Filtration Stages | Description | Assessment criteria | Count |
|---|---|---|---|
| 1st filtration | Identification of the relevant studies from the selected database | Search Category and keywords using the filter “” | 12315 |
| 2nd filtration | Exclude the studies based on their titles | Title = Search terms | 9965 |
| 3rd filtration | Exclude the studies based on their abstract | Keywords inside the abstract | 2347 |
| Final filtration | Obtain selected relevant articles | Address IE and QC | 44 |

The IE criteria used to tune this review were the following: “IE1: Is the article context related to ITG?”; “IE2: Is the article context related to IoT?”; “IE3: The description of the article is related to the research context?”; “IE4: Do the findings of the article provide valuable insights to define one or more ITG enablers?”.

Quality criteria were also applied. The authors have selected only articles from SJR Q1/Q2 classification, ranking ERA A/B, or ranking Qualis A1/A2/B1. In the end, 44 articles were selected and analyzed. Following the concept-centric approach [30], Table 6 lists the enablers for IoT implementation and respective references.

Table 6. ITG enablers SLR for IoT: Former list of ITG enablers for IoT implementation

| Enablers | ID | Recommendations | References from literature |
|---|---|---|---|
| Principles, Policies, and Frameworks | F1 | Promote interoperability via decentralization. | [70] |
| | F2 | Promote collaboration between organizations. | [71] |
| | F3 | Implementation of trust. | [72] |
| | F4 | Implementation of transparency. | [72] |
| | F5 | Implementation of data privacy and data protection. | [72] |
| | F6 | Implementation of accountability. | [72] |
| | F7 | Interiorization of risk management. | [73] |
| | F8 | Cooperation between organizations in building policies. | [74] |
| | F9 | Governance framework application. | [75] |
| | F10 | Strategic policies to promote innovation. | [74] |
| | F11 | Include users’ privacy issues in IoT policies. | [76] |
| | F12 | Operational principles are aligned with IoT procedures. | [74] |
| | F13 | Include cybersecurity and digital policies in IoT policies. | [77] |
| | F14 | Governance framework guides the management team in IoT implementation. | [72] |
| Processes | P1 | Strategy processes to coordinate IoT processes. | [78] |
| | P2 | Business processes to align the IoT process with business models. | [79] |
| | P3 | Governance processes to decompose and decentralize the business processes. | [79] |
| | P4 | Information processing towards business decisions. | [80] |
| | P5 | Implementing a sound data management process. | [81] |
| | P6 | Implementation of data analytics process. | [81] |
| | P7 | Implementing application management process to promote scalability. | [82] |
| | P8 | Implementing application monitoring process to guarantee business continuity. | [83] |
| | P9 | Implementation of application security management in development process. | [75] |
| Organizational Structures | O1 | Assignment of roles, responsibilities, and tasks in IoT. | [84] |
| Culture, Ethics, and Behavior | B1 | Spread social culture in IoT implementation. | [85] |
| | B2 | Organization’s culture aligns with identity, autonomy and trust protection of IoT users. | [82] |
| | B3 | Organizations implement his culture and values in IoT acceptance. | [85] |
| | B4 | Ethics integrates social behaviors, privacy, and integrity in IoT implementation. | [86] |
| | B5 | Implementation of awareness in people’s attitude and motivation. | [87] |
| Information | I1 | Information research techniques for IoT support. | [88] |
| Services, Infrastructures and Applications | S1 | IoT services promotes sustainability. | [89] |
| | S2 | IoT services are built on top of strong standards and protocols. | [90] |
| | S3 | IoT infrastructures it is aligned with continuity of investment. | [85] |
| | S4 | Ensure IoT services improve the organization’s efficiency by being aligned with business needs. | [90] |
| People, Skills, and Competencies | C1 | Integration of people in IoT. | [85] |
| | C2 | Socio-technical skills to promote automation. | [87] |
| | C3 | Implementation of strategic skills for goals guidance. | [91] |
| | C4 | Implementation of information skills for requirements analysis. | [91] |
| | C5 | Implementation of organization skills to improve decision making. | [91] |
| | C6 | Implementing people as an important role in IoT acceptance. | [85] |

## 3. Delphi Method

The Delphi method has been a popular tool in information systems research [59]. It aims to obtain the most reliable information from a group of experts [60] via a series of questionnaires with feedback-controlled opinion [61] to reach a reliable consensus amongst them [59]. The five-point Likert-type scale is the preferred tool, with the cut-off point set within score three and four [62]–[65]. In this research the cut-off is 3.5. Previously used in ITG domain [66] the Delphi method was then adopted by the authors to reach consensus regarding the final list of ITG enablers for IoT implementation.

Eleven experts were invited to participate in this research with a 37 percent drop off rate (7 experts accepted). The Delphi method was divided into three rounds. By the end of the third round none of the participants quit the study. According to literature, the tendency is reducing the number of participants in each new round [67]–[69]. Another point that is important to highlight is that this Delphi study took more than 45 days, as also recommended in literature [60]. Table 7 details all the rounds of the Delphi. The first round was used to validate the initial list of recommendations extracted from the literature using a degree of concordance between 1 and 5, and to increase the list with new recommendations provided by the participants. The second round was used to determine the level of efficiency from each recommendation on each ITG enabler in IoT, identifying a top 10 most important recommendations for an IoT implementation. The third round was used to increase the consensus of concordance and efficiency within the group about the recommendations. Table 6 lists the enablers for IoT implementation and respective references.

Table 7. Delphi: List of rounds

| Phase | Date | | Input | Output | Participants | |
|---|---|---|---|---|---|---|
| | Begin | End | | | Invited | accepted |
| Round 1 | 01/02/2019 | 28/02/2019 | ITG definitions<br>ITG Enablers for IoT | New List of recommendations and their definition | 11 | 7 |
| Round 2 | 19/03/2019 | 06/04/2019 | List recommendations from round 1 | Top 10 recommendations and efficiency level on each recommendation. | 7 | 7 |
| Round 3 | 12/04/2019 | 06/05/2019 | List of recommendations from round 2 | Consensus in the efficiency level and top 10 recommendations | 7 | 7 |

### *3.1 First Round*

During the analysis of the first round, an exclusion criterion was created to factor out the weakest recommendations on the initial list. The exclusion criteria used was: any recommendation is excluded if the average rate of the recommendation is equal or below 3.5. After the first round, the confirmatory phase led to the exclusion of eight recommendations (red bars in Figure 5) from the initial list (F8, F11, F14, P3, B1, I1, C3, and C5). In addition, two recommendations were merged (F5 and F11) since according to participants they represent the same objective. The authors have created graphs for each ITG enabler for IoT.

Moreover, by exploring the qualitative information collected from the interviewees, the authors were able to add nine new recommendations. Table 8 presents these new recommendations which are: F6; F11; P3; P10; O2; I1; S5; S6; C3. It must be noted that the new recommendations (when possible) took the IDs of the removed ones.

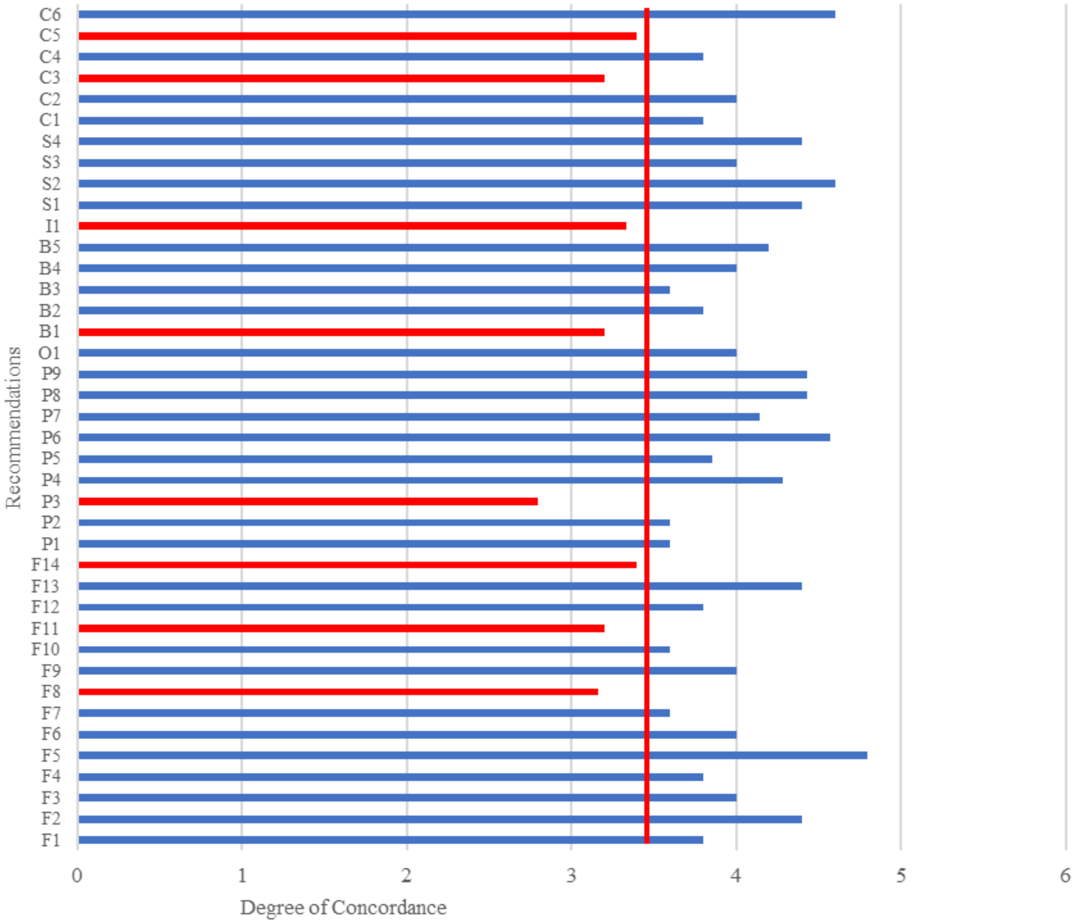


Fig. 5. List of excluded recommendation

Table 8. Delphi – first round: Final list of ITG enablers for IoT implementation

| ID | Recommendations |
|---|---|
| F1 | Promote interoperability via decentralization |
| F2 | Promote collaboration between organizations |
| F3 | Implementation of trust |
| F4 | Implementation of transparency |
| F5 | Implementation of data privacy and data protection |
| F6 | **IoT agile principles** |
| F7 | Interiorization of risk management |
| F8 | Governance Framework Application |
| F9 | Strategic policies to promote innovation |
| F10 | End-to-End security principles |
| F11 | **Data audit principle** |
| F12 | Operation Principles are aligned with IoT procedures |
| F13 | Include Cybersecurity and digital policies in IoT policies |
| P1 | Strategy processes to coordinate IoT processes |
| P2 | Business processes to align IoT processes with business models |
| P3 | **Problem identification processes** |
| P4 | Information processing towards business decisions |

| ID | Recommendations |
|---|---|
| P5 | Implementing a sound data management process |
| P6 | Implementation of data analytics processes |
| P7 | Implementing application management process to promote scalability |
| P8 | Implementing application monitoring process to guarantee business continuity |
| P9 | Implementation of application security management in development process |
| P10 | **Digitalization processes** |
| O1 | Assignment of roles, responsibilities, and tasks in IoT |
| O2 | **Implementation of accountability** |
| O3 | Responsabilization assignment matrix |
| B1 | Organization's culture aligns with identity, autonomy and trust protection of IoT users |
| B2 | The organization implements his culture and values in IoT acceptance |
| B3 | Ethics integrates social behaviours, privacy, and integrity in IoT implementation |
| B4 | Implementation of awareness in people's attitude and motivation |
| I1 | **Data exchange between organizations** |
| S1 | IoT services promote sustainability |
| S2 | IoT services are built on top of strong standards and protocols |
| S3 | IoT infrastructures it is aligned with continuity of investment |
| S4 | Ensure IoT services improve the organization's efficiency by being aligned with business needs |
| S5 | **Predictive technologies to support decision makers** |
| S6 | **Service delivery management to improve scalability** |
| C1 | Integration of people in IoT |
| C2 | Socio-technical skills to promote automation |
| C3 | **User experience to improve effectiveness** |
| C4 | Implementation of information skills for requirements analysis |
| C5 | Implementing people as an important role in IoT acceptance |

The next section presents the second round of Delphi.

### *3.2 Second Round*

The second round was sent on March 19th to the participants with a two weeks deadline to fulfil the questionnaire. This round aimed to get a rate in terms of efficiency of each ITG enabler recommendation validated in the first round, using a score between one (not efficient) and five (very efficient). In addition, the participants were invited to point out from the list of recommendation which ones they believed to be the top 10 for an IoT implementation. After gathering all the answers, ranking points were used to define each position. First choice gets 10 ranking points and the 10th gets 1 ranking point. Table 9 presents the overall top 10 recommendations.

Table 9. Delphi – Round 2: Top 10 recommendations

| Top10 | ID | Recommendations | Ranking Points |
|---|---|---|---|
| 1 | F5 | Implementation of data privacy and data protection. | 49 |
| 2 | P5 | Implementing a sound data management process. | 36 |
| 3 | P6 | Implementation of data analytics processes. | 33 |
| 4 | S2 | IoT services are built on top of strong standards and protocols. | 31 |
| 5 | F10 | End-to-End security principles. | 18 |
| 6 | F8 | Governance framework application | 17 |
| 7 | P2 | Business processes to align IoT processes with business models. | 16 |
| 8 | F2 | Promote collaboration between organizations. | 14 |
| 9 | C2 | Socio-technical skills to promote automation. | 14 |
| 10 | O1 | Assignment of roles, responsibilities and tasks in IoT. | 13 |

### *3.3 Third Round*

In the third round, participants were asked to review their answers from round two according to the group's average. The objective of this round was to deliver more consensual results in terms of ITG enablers efficiency and in the top 10 recommendations. Comparison between round two and three is detailed in Figure 6.

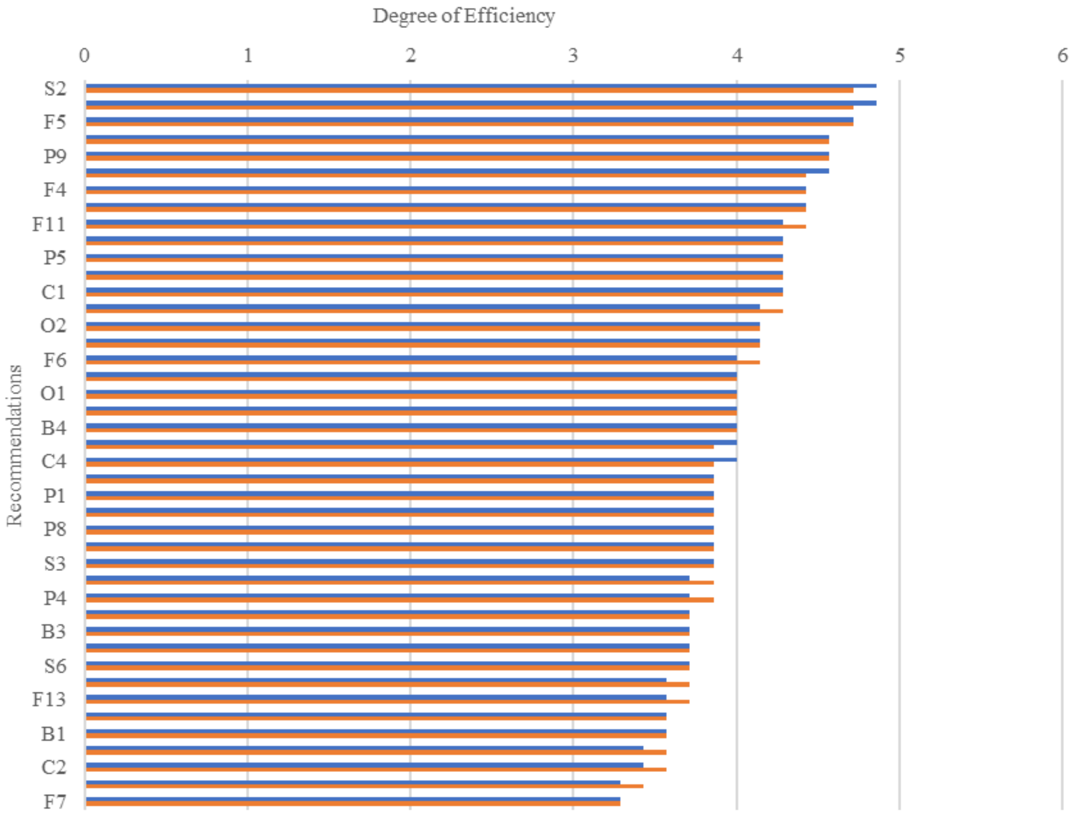


Fig. 6. Delphi – Round 3: Comparison between efficiency scores (Round 2 – Orange; Round 3 – Blue)

Table 10 presents the ten most important recommendations by the participants involved in the Delphi research.

Table 10. Delphi – Round 3: Tuned top 10 recommendations

| **Top 10** | **ID** | **Recommendation** | **Ranking Points Round 2** | **Ranking Points Round 3** | **Delta** | **Position** |
|---|---|---|---|---|---|---|
| 1 | F5 | Implementation of data privacy and data protection | 49 | 59 | +10 | --- |
| 2 | S2 | IoT services are built on top of strong standards and protocols | 31 | 45 | +14 | ↑+2 |
| 3 | P5 | Implementing a sound data management process | 36 | 42 | +6 | ↓-1 |
| 4 | P6 | Implementation of data analytics processes | 33 | 40 | +7 | ↓-1 |
| 5 | F10 | End-to-End security principles | 18 | 30 | +12 | --- |
| 6 | F8 | Governance Framework Application | 17 | 27 | +10 | --- |
| 7 | O1 | Assignment of roles, responsibilities, and tasks in IoT | 13 | 18 | +5 | ↑+3 |
| 8 | P2 | Business processes to align IoT processes with business models | 16 | 17 | +1 | ↓-1 |
| 9 | F2 | Promote collaboration between organizations | 14 | 10 | -4 | --- |
| 10 | O2 | Implementation of accountability | 10 | 10 | 0 | New |

The next section presents the demonstration and evaluation.

## 4. Demonstration and Evaluation

An experienced IoT organization was assessed in order to validate if the proposed recommendations were used in their IoT projects and if they resulted in a positive impact. The interviewee has more than 20 years of experience in the field and the targeted organization has dozens of ongoing IoT projects. However, for confidentiality reasons we are not able to provide information on the organization nor the name of the interviewee.

We asked for the interviewee's opinion regarding the most important and efficient recommendations obtained (Figure 6) and if the top 10 recommendations were useful in an IoT project. Regarding the full set of mechanisms, qualitative information is provided in Table 11. The researchers made an effort to collect more qualitative information about the top 10 mechanisms, but others were also discussed. On the top 10 mechanisms, the interviewee argued that "…all recommendations mentioned in the top 10 recommendations are useful in an IoT project to bring more effectiveness of the solution and to meet the requirements requested by the customer during the implementation. However, I must say that we did not feel the need to implement B2 since we do not feel that acceptance depends on meeting the culture and values in this organization". This remark is due to the fact that this organization has a strong involvement in IoT projects, and the workers are aligned with that mindset. However, in less experienced organizations this recommendation may be important to consider. In Table 11, you can see the detailed comments of the interviewee for each recommendation.

Table 11. Evaluation - interview: Comments per recommendations

| ID | Recommendation | Comments |
|---|---|---|
| Q1 | Implementation of data privacy and data protection (F5) | "This recommendation is essential to exist during an IoT implementation and after the implementation and our organization implements from the begin of the implementation until the end solution." |
| Q2 | Implementation of data privacy and data protection (F5) | "There is a constant worry and care to have this during an implementation." |
| Q3 | IoT services are built on top of strong standards and protocols (S2) | "In our IoT implementations we normally use protocols in the levels of encryption, access and in data formatting and some example of protocols are AES, LoRa, IPSec, SSH, SHA and REST protocol." |
| Q4 | Implementing people as an important role in IoT acceptance (C5) | "People are essential during the implementation and after the solution is implemented. In addition, it is important to consider that people and processes must be adaptive based on the solution, therefore we tried to include the stakeholders during the implementation process to leverage the acceptance." |
| Q5 | Implementing a sound data management process (P5) and Implementation of data analytics processes (P6) | "Yes we use these recommendations and we put more emphasis into data identification and data validation, because there is uncertainty in data obtained by the solution, so there must be several ways to test the data and to validate the data using data harmonization." |
| Q6 | Promote collaboration between organizations (F2) | "If an organization has the idea to be alone in the IoT sector will not be successful. So, a partnership is essential during an IoT implementation. The interaction was made at the same level between organizations (IoT and data levels)." |
| Q7 | Governance Framework Application (F8) | "Our organization didn't use any governance framework during an IoT implementation, therefore this recommendation in my perspective is not useful." |
| Q8 | Business processes to align IoT processes with business models (P2) | "Yes, we tried to implement this recommendation, but the trend for the future is the opposite, because if the organization only focus to align the IoT processes to the business models will lose scalability in IoT where in the long term will not bring many benefits in terms of business to the organization." |
| Q9 | Assignment of roles, responsibilities, and tasks in IoT (O1) | "Normally the people already have their roles in the organization, we only make the adaption of processes, and people only change tasks and not functions." |

| ID | Recommendation | Comments |
| --- | --- | --- |
| Q10 | F5, P9, O2, B2, I1, S2, C5 | "The organization in the IoT implementation use all of the recommendations to bring more efficiency into the solution and we put more focus in the S2 recommendation "IoT services are built on top of strong standards and protocols". In addition, the organization focused on the use of open standards in their IoT solutions." |
| Q11 | End-to-End security principles (F10) | "The organization implements it through all IoT projects. Actually, we turned it native using IPv6." |
| Q12 | Implementation of accountability (O2) | "The organization tries to implement this recommendation but there is a flaw in the assignment of responsibilities which makes the IoT implementation less efficient, due to a lack of responsibility level in the new tasks of the people." |
| Q13 | Implementation of application security management in development process (P9) | "The organization do not apply this recommendation in particular, because the solution already has security tools that applied security management process." |
| Q14 | The organization implements his culture and values in IoT acceptance (B2) | "Any implementation of values and culture was not made in the IoT solution because the acceptance does not depend on meeting the culture and values but instead depends on the effectiveness of the solution, therefore we do not implement this recommendation." |
| Q15 | Data exchange between organizations (I1) | "We use this recommendation, but this exchange of information did not increase efficiency, instead increase the credibility, due to the validation of data to support the decision makers to getting the right decisions for the business. Also, increased the speed of acceptance and the priority level of IoT. This exchange of information between organizations brings always new ideas, new solutions." |

## 5. Research Synthesis and Findings

At the end of this research, some literature statements were reinforced, and others elicited and added as novel insights to the body of knowledge. The following paragraphs intend to connect the main findings of this research and the literature of the area.

Organizations do not implement IoT for matters of marketing or image. The IoT adoption, like any other technology, should be a strategic decision [92] grounded on business needs and aligned with business objectives [93]. Therefore, new business processes must be designed or a redesign of current ones is required to incorporate IoT technology in an organizations' business (P2).

A business process is usually defined as a set of activities that together perform a business objective [94]. With the inclusion of IoT technology in business processes new activities will be added; therefore, new roles and responsibilities must be defined (O1) so that accountability can be established (O2) and absence of responsibility in IT failures is avoided [84].

IoT systems collect and manipulate huge amounts of data [95] and privacy must be assured as well as protected from threats (F5). The exponential growth of data in IoT systems and the need to be controlled calls for a solid Data Management process (P5) which is seen in literature as a core process for IoT success [96]. Plus, since IoT projects are complex [97] and data security seems to be a critical issue, end-to-end security principles (F10) must be evangelized. One way to ensure security is by adopting one or more of the many standards and protocols (S2) that already exist [98].

Information is currently one of the key assets of organizations [99] and Information systems have an important role in producing reliable information from raw data [46] so that managers can make decisions accordingly [92]. IoT systems are no exception; thus, the implementation of capable analytics processes (P6) are imperative to create reliable information and knowledge from all the collected data.

Many IoT projects require the involvement of other organizations [71]. This increases the potential risks of the project and therefore special attention should be paid to the efficient collaboration of the respective organizations (F2).

Nowadays, organizations are not able to compete or even survive without a strong IT function [99]. With the increasing importance of IT in organizations' success, enterprise governance of IT became critical to ensure business/IT alignment [100]. Thus, the implementation of an ITG framework (F8) is advised and well seen by the experts.

## 6. Conclusions, limitations and future research

At the beginning of this investigation the purpose was to identify a list of the main ITG enablers for IoT implementation, thus helping managers improve IoT project results with better governance. At the end, the main conclusions of this investigation are presented. The enabler "processes, principles, frameworks and policies" appears to be the most investigated in literature. This makes sense since many researchers have focused their research on evolving and extending ITG frameworks in different organizational contexts. The application of ITG frameworks in IoT is not an exception. Nevertheless, few studies exist clearly exploring how ITG may help IoT implementation projects. Both enabler categories "people, skills and competencies" and "information" are the less explored ones in literature

According to the practitioners, the less relevant ITG enabler categories are "Culture, Ethics, and Behaviour" and "Information". Such conclusion is grounded on the absence of recommendations of those enablers on the defined top 10, and according to the rate of efficiency the maximum score in the group's average was four in the Delphi results. However, the authors believe that the scarce enablers in the "information" category may have influenced this conclusion. On the contrary, "Principles, Policies and Frameworks" (4 of the top 10) and "Processes" (3 out of 10 in top 10) are seen as the most relevant enabler categories for IoT projects. All the enablers about data seem to be essential in IoT. Three of the first four enablers in the top 10 are Data-oriented. Implementation of roles and responsibilities are seen as an important step since the beginning of an IoT implementation. People still have an active role in IoT projects, thus managers should increase efforts in IoT acceptance by people. The "Process" category has a high correlation with "Principles, Policies, and Frameworks", given the focus in data and how organizations will manipulate that which is obtained by IoT systems. Such correlation is essential since the processes of data management and data analytics are critical to extracting information from data, and the implementation of data privacy and data protection is necessary to assure data integrity and trustful information. It is important to assign roles and responsibilities to the people involved in an IoT project, convincing them that it is necessary to adapt their tasks into the IoT implementation as well as to adapt the current processes of the organization to increase the efficiency of the implementation. When more than one organization is involved in the IoT project, the focus on the level of data must be reinforced since multiple organizations may need to access and use data to retrieve valuable information and knowledge necessary for their business. In addition, organizations working in silos may not succeed in the long term, because the collaboration between organizations may increase the success rate of an IoT implementation.

Last but not least, people seem to be a considerable barrier to increase the acceptance of IoT, and it is suggested (C5) to involve people from the beginning. Therefore, they can understand that these abnormal patterns always bring new ideas and new solutions into their business. The results indicate that data privacy, data protection, and data analysis are currently the most relevant enablers to consider in an IoT implementation because they increase the efficiency of the solution and data credibility.

This investigation has some limitations as well. The lack of studies relating to ITG enablers with IoT forced the authors to perform a more interpretive analysis of most studies. Moreover, some experts did not accept our invitation to participate in the Delphi study, reducing the possible number of contributions. The study has limitations regarding the type of organization given that it was carried out in the banking industry of a particular country, Portugal. Future research should go deeper in exploring the ITG enablers for IoT implementation in different kinds of organizations taking into account contingency factors such as regional differences, size of the organization, country, type of control, public or private, amongst others. An exploratory study upon each ITG enabler/mechanism can lead to a strengthening of the findings concerning this topic. Finally, we would recommend a quantitative study to be more precise in generalizing the order of importance in each ITG enabler for IoT implementation. We are currently working in the implementation of part of these mechanisms in an organization.

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# Fused or Unfused? The Parable of ERP II

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**Abstract:**
One of the major visions is having one system that covers all business functions and satisfies virtually all the standard processes and routine transactions within organizations. In the last decade, several academics and practitioners have predicted the rise of what is called enterprise resource planning systems II (ERP II). ERP II was sought to be a digital platform that is capable of supporting timely decision-making through covering all business functions' processes through having preloaded modules that will minimize the need for external systems like separate customer relationship management (CRM), e-business platforms, and supply chain management (SCM) systems, among others. While ERP systems nowadays have matured, and several packages come with CRM modules and other solutions, however separate CRM systems are still widely adopted by organizations. Thus, this study investigates why organizations that currently have ERPs with CRM modules are still investing in separate CRM systems. Our results show that the current ERP systems did not reach the ERP II state as envisioned, as most organizations are inclined to adopt separate CRM systems. Thus, we have presented five main reasons for this inclination, which are: scoping during ERP implementations, costs, features and functionalities, user-friendliness and ease of use, and finally integration with e-business platforms.

**Keywords:**
ERP systems; CRM systems; ERP II; ERP selection; ES integration.

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## 1. Introduction

Enterprise Resource Planning (ERP) systems evolved in order to address the islands of information challenge, or what is known as *stovepipe systems* within organizations. Stovepipe systems are functional systems, which lack seamless integration between the different business functions in organizations. Thus, ERP systems were created to support and solve the integration challenges among the various business functions through using one logical database with several functional modules [1]. Because ERP systems are pre-designed to fit many different organizations, ERP systems come with pre-loaded and embedded best practices and industry standard processes [2]. ERP vendors and their key customers often jointly develop and define these best practices and processes. Hence, those best practices do not necessarily represent how the majority of enterprises conduct their business [2]. Due to their size and complexity, ERP systems' implementations require a substantial amount of resources and careful project management procedures [3].

Since 2000, several authors and practitioners have predicted that customer relationship management (CRM) modules, domain-specific operations, and e-business enablement will become standard solutions in future ERP packages [4]. They called it ERP II, as an evolution and extension to the traditional ERP. Indeed, major ERP vendors have responded to this vision and currently offer pre-customized domain-specific systems, e-business ready modules or interfaces, and CRM modules and applications. While most ERP systems have a CRM module included, such as the major closed source and open source ERP packages, however in practice, we still observe that a large number of organizations is still adopting stand-alone CRM systems. Thus, in this paper we attempt to explore the reasons why organizations are still investing in separate CRM systems, which might not even be integrated to other core processes of the company, instead of using the CRM module that comes with their ERP system. Hence, we have conducted a multiple case study in which we have interviewed informants from seven case organizations in Austria, Egypt, Norway, and the United Kingdom. In addition, in an attempt to capture a wider spectrum of different perspectives on the topic under-study, we have also interviewed various ERP stakeholders including implementation partners, consultants, and vendors. We would therefore like to explore the main reasons and motivations that lead organizations that are using an ERP system already, for adopting a separate CRM system. The results from this research may aid ERP vendors in identifying the current weaknesses of their systems (*if any*) and aid them in developing future full-fledged systems that can replace most of the organisational digital infrastructure and scattered applications.

This paper is organized as follows: the following section presents the study's background literature. In section 3, we introduce our target cases and research methodology. Research results and discussion are presented in section 4, and finally our conclusions and recommendations for future research are provided in section 5.

## 2. Literature Background

This research focuses on the observed phenomenon of organizations investing in a separate CRM system even though several of these organizations might already have a CRM module in their acquired ERP system. The authors have observed this trend in several companies in practice. Below, we introduce the basic concepts and background literature for this study.

### *2.1 ERP Systems*

ERP systems are the largest type of enterprise systems. Enterprise systems are enterprise-wide applications, which are virtually used by the various business functions inside organizations. Other types of enterprise systems include CRM systems, supply chain management (SCM) systems, and any other enterprise-wide scale system. ERP systems handle basic corporate and business functions, such as finance, human resources, materials management, sales and distribution [5]. In the 1990s, ERP systems were proliferating among companies and turnovers of software vendors were high [6]. ERP systems were initially targeting large enterprises, however due to market saturation, vendors started to create lighter versions that can fit small and medium-sized enterprises (SMEs) [7]. With the current trend of moving into the "cloud" and the accompanying change to subscription-based payment plans [8], the business model of many software vendors has changed. The most popular players in the market today are SAP, a German company with customers in 190 countries and an annual turnover of ca. 25 Billion Euros [9], and Oracle, a US-based company, which is also known for their database management systems among other products, has ca. 420 000 customers and a current annual turnover of 37 Billion USD [10].

In general, ERP implementation projects involve several stakeholders including the internal IT staff and key business users from inside the organization, as well as, external consultants, or consultants from the implementation partners/vendors [1, 11]. It is recommended that adopting organizations should develop control mechanisms to ensure that the external consultants work in favor of the project and its goals [12]. ERP system implementation projects may differ from traditional system implementations in scale, scope, complexity, organizational changes, project costs, and the need for business process reengineering [13]. The percentage of ERP project failures is over 60% and half of all top-10 failures of all time are from market leading ERP vendors [14]. A more recent survey conducted by Panorama Consulting Solutions reports that 74% of the participating organizations in the survey have crossed their estimated ERP implementation budgets for several reasons, but one of the main reasons was due to unexpected changes in organizational or technical requirements [15]. In addition, 59% of the projects crossed their go-live schedules, mainly due to project scoping issues [15]. Moreover, the survey results also show that 56% of the organizations have suffered from production disruptions for varying time periods [15]. Software vendors have established so-called 'best practices'. These are primarily processes, which are supposed to be the ideal and standard practices in particular industries. Software vendors dedicated a lot of effort in investigating and identifying these practices from organizations and academic theories [16]. Many ERP packages are implemented using these best practices, meaning that the implementing organization adopts all or parts of these best-practices. This implementation type is called *"vanilla"*. When implementations are made which mainly use the suggested processes, most organizations need to commit themselves to some form of business process reengineering [16]. While this usually involves costs and efforts, Robey et al. [5] state that the primary benefit from implementing an ERP system might result from adopting new business processes.

In general, ERP system implementations are complex and resource-intensive projects [17], spanning from the *adoption decision*, the *acquisition* phase, the actual *implementation* phase to the *use and maintenance* phase, the *evolution* phase, and eventually followed by the *retirement* phase [18], as depicted in the figure below.


Fig. 1. The ERP lifecycle framework. Adapted from [18].

### *2.2 ERP System Selection*

The selection of an ERP vendor and the respective product is a part of the acquisition phase in the ERP Lifecycle framework. Somers and Nelson [13] present several critical success factors (CSF) across the stages of an ERP implementation: they identified that besides architecture choice, the most important success factors in the selection phase are clear goals and objectives, partnership with vendor, top management support as well as a careful selection of the package. Especially the CSF "clear goals and objectives" and "careful selection of the package" seem at first glance to be two potential answers to the research question of this study.

During the selection phase, system and organization fitness is regarded as a crucial issue. Several information systems implementations fail due to the selection of a non-fitting system [1]. The fitting process happens between the ERP system and the organization needs, requirements, and expected future evolvement and scalability. The topic of "fit" has been regarded as of paramount importance and has been frequently discussed in IS literature in general, and specifically in enterprise resource planning domain [1]. A wrong ERP system selection would either totally fail the project, or critically weaken the system and negatively affect the company's performance [19], and also may lead to an early ERP retirement in some cases [20]. When deciding on the desired functionalities in the potential ERP, it is useful and, in most cases also required, to separate the “nice to have” from the “need to have” functionalities [21], and to focus on the goals and objectives that are to be achieved with the system. In practice, consultants regularly conduct an evaluation of the requirements, often however, requirements are only inferred and indirectly suggested by the ERP adopting organizations [1].

In literature, several studies aimed at identifying factors that could potentially affect the ERP selection outcome in organizations, and provided recommendations and criteria to optimize the selection process [1]. For instance, a study presented several factors that may affect the selection criteria, which include the ERP-to-organization fitness as an important factor [22]. During the selection phase, it therefore seems beneficial to scrutinize the current processes, before matching the company’s requirements with the features and functionalities of the potential system [1]. In addition, Deep et al. [23] developed a framework for the ERP system and vendor selection processes. The framework presents the various stages and phases in the selection process, which starts with the requirements and project planning, identifying potential vendors, evaluation, and finally ends with the selection of the appropriate ERP package. The framework also illustrates several iterative tasks to be accomplished by the project team at each stage. Thus, the ERP selection process is a challenging task. This is mainly due to the scarcity of available resources within organizations, the complex nature of ERP packages, and the various ERP system alternatives in the market [24]. In addition, Esteves & Pastor (1999) argue that the price of the package, training and maintenance services provided by the vendor, return on investment (ROI) estimation, and the contractual agreement are defined during the selection process.

In our theoretical background, we focus on the selection process of ERP systems. We do so, because we hypothesize that the main grounds for acquiring a separate CRM either lie in the selection process of the ERP system (in other words: has the wrong ERP solution been chosen?) or this happened due to other reasons, such as the ERP system’s characteristics or issues that cannot be influenced directly (e.g. internal political decisions).

### *2.3 CRM Systems*

Customer relationship management as such, is a comprehensive strategy, and includes the processes of acquiring, retaining, and cooperating with segmented customers in order to maximize the value for the organization and its customers [25]. This includes the full integration of marketing, sales, and customer service functions and processes in order to maximize efficiency and effectiveness in delivering customer value [25]. These processes can be supported technologically by CRM systems, which manage all the channels, interactions, and touch and contact points between the organization and the customers.

CRM literature points out the importance of a single-view of the customer across all contact channels [26]. In addition, CRM systems have been widely adopted and aided in helping organizations to reach and contact customers, and to generate comprehensive analyses of their customers by collecting, storing and analysing customer data [27].

CRM systems are typically considered a type of Enterprise Systems. Even though existing literature differentiates between the scope of ERP systems that mainly capture operational (internal) data, and CRM systems’ scope of focusing and capturing customer (external) data [28], however most ERP systems nowadays include a customer relationship management module or related applications.

With many CRM solutions establishing themselves in the market, such as Microsoft Dynamics, Salesforce, SugarCRM, HubSpot and other providers, the CRM market has been estimated to a total of 12 Billion USD in 2019 [29]. According to Forbes [30], Salesforce is the current market leader and holds a market share of more than 19% of global share. Salesforce is a cloud-only provider, which, besides sales modules, offers modules for marketing, service desks, analytics, community (social networks) and e-commerce. In Reinartz et al. [26], they state that the use of CRM systems is projected to advance the ability of an organization to endure profitable customer relationships by enabling information to be integrated and shared smoothly. Customer relationship is assumed to be a people-driven process [26], meaning that building and enforcing customer relationships have to come from the organization and the people therein and software can only support this process. Prior research in this area found that by implementing a CRM system without established processes and people in place, the actual customer relationship performance may drastically deteriorate [26].

### *2.4 ERP II*

The ERP II vision refers to an extended version or the next generation of ERP systems [31]. In 2000, Gartner group defined ERP II as a business strategy and a set of industry-domain-specific applications, which optimize enterprise and inter-enterprise, collaborative-operational and financial processes, in order to build and maximize customer and shareholder value [32]. Thus, ERP II was envisaged to virtually provide all the related integrations among front- and back-office systems (ERP I), plus all system functionalities that are included within CRM, supply chain management (SCM) systems [4, 31], and provide business intelligence (BI) capabilities [33]. Most of these processes and functions would mainly be available through modular on-demand add-ons to the system, like CRM-related solutions, data warehousing applications, and web portals [33, 34].

Besides sales force automation (SFA) and cost (SFC) management, ERP II was also foreseen to integrate all e-commerce related processes with the corporate supply chain [33]. Figure 2 presents an overview of the organizational areas and processes that ERP II is intended to cover. The areas are CRM, PLM (product lifecycle management), SRM (supplier relationship management), HRM (human resource management), CPM (corporate performance management), and SCM. In addition, ERP II was envisioned to provide back and front-end applications to enable business-to-customer, business-to-business and business-to-employee operations. Moreover, ERP II should facilitate the enterprise application integration (EAI) with other systems [4]. Thus, due to their massive scale and coverage of the micro and macro environments' stakeholders, and the different business functions and operations, ERP II systems were and are expected to be very complex to implement [31, 34, 35].

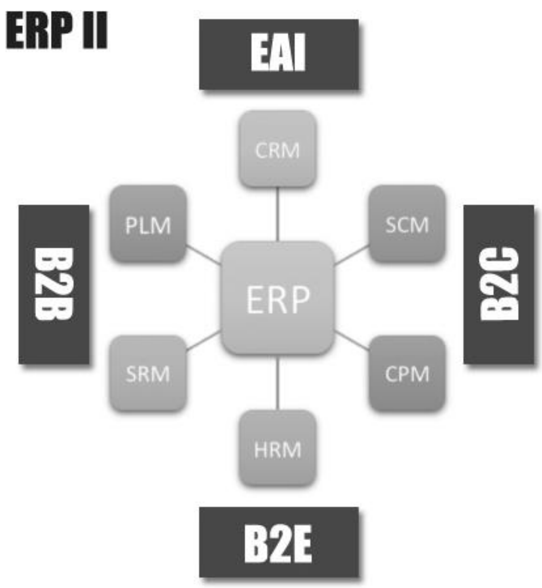


Fig. 2. ERP II Umbrella. Adapted from [33].

ERP II implementation projects should not be only regarded as IT projects, they rather should be considered as business projects. This is mainly due to the considerable time of business engagement of the various key employees from the various business functions within organizations in contrast to their IT departments' peers [34]. In the year 2005, Møller argued that Gartner's vision of the next generation ERP (ERP II) has been matched by ERP's vendors as major ERP systems currently (in 2005) have several interfaces, modules, and add-ons to meet that vision [33]. Looking now, we can see that most ERP systems facilitate EAI within organizations (e.g. SOA), and their SCM related modules have satisfied the need for adopting separate SCM systems for many organizations, however, we argue that this is not yet the case when it comes to CRM systems. In general, the ERP literature lacks sufficient research on exploring the status of "ERP II" initiatives in the industry [33]. Based on the authors' experiences in the industry, it is hypothesized that organisations still prefer to have stand-alone CRM systems along with their ERP systems, instead of having all-in-one solutions. Thus, in this paper we attempt to test this hypothesis and explore the reasons why organizations are still investing in separate CRM systems, which might not even be integrated to other core processes of the company, instead of using the CRM module that comes with their ERP system.

## 3. Research Methodology

This research followed an explorative research methodology, which can potentially aid in providing a better understanding of the phenomenon or problem understudy [36]. In general, exploratory research is a satisfactory method for investigating and explaining why certain phenomena occur [37]. Exploratory research is usually undertaken for three main purposes, namely analysing a situation, assessment of alternatives and discovering new ideas and phenomena [38]. One of the foundations of this genre of research is the use of a hypothesis, in which the researchers test the viability of certain hypotheses or research questions [39]. Thus, the authors hypothesized and questioned the viability of ERP II in practice. Specifically, the authors conducted a multiple case study [37] with ten semi-structured qualitative interviews [36] in organizations, plus six additional interviews with other stakeholders. According to Yin [37], a case study research method is recommended when "how" and "why" questions are probed, when the researcher has diminutive control on the events, and when the focus of the investigator is on a current phenomenon that occurs in a real-life context. According to Thomas [40], case studies can include the analyses of events, persons, decisions, periods, projects, institutions, or any other systems that are scrutinised and studied holistically through one or more research methods.

The data collection process was conducted between February 2017 to June 2018. The interviews were carried out in various organizations working in different industries, and within various geographical regions. The industries included: banking, business consulting, construction building information management (BIM), retail, manufacturing, and telecommunications. Other interviews have also been conducted with ERP consultants, implementation partners and vendors. The participants included a mixture of stakeholders who have been involved in ERP and CRM systems implementations. Altogether sixteen interviews gathered information from these different stakeholders. The informants had experience in various local, international, and open source ERP and CRM systems. More details regarding the sampling and data collection process are presented in section 3.2.

In the following table, the informants' details from the eight target cases and other interviewees are introduced in more details. The company names are fictitious to preserve anonymity.

Table 1. Overview of cases and informants.

| Case | Industry | Size | Location | Informant |
|---|---|---|---|---|
| Organization 1 | Banking | Large | Norway | Customer service employee |
| Organization 2 | Consulting | Small | United Kingdom | Marketing manager |
| Organization 3 | Consulting | Small | Austria | Marketing employee<br>Head of sales |
| Organization 4 | Construction-BIM | Large | Norway | IT Application consultant |
| Organization 5 | Clothing Manufacturer | Small | Norway | Sales manager |
| Organization 6 | Retail & Food Manufacturing | Large | Egypt | Senior ERP Consultant |

| Case | Industry | Size | Location | Informant |
|---|---|---|---|---|
| Organization 7 | Telecom | Large | Egypt | Sales employee<br>Marketing employee |
| Organization 8 | Banking | Large | Norway | Senior business support employee |
| Imp. partner 1 | Implementation Partner | Large | Czech Republic | Senior SAP Consultant |
| Imp. partner 2 | Implementation Partner | Small | Egypt | Junior implementation consultant |
| V | ERP Vendor | Medium | Egypt | General manager<br>ERP senior consultant |
| Cons 1 | Not applicable | Not applicable | Norway | Independent ERP consultant |
| Cons 2 | Not applicable | Not applicable | Sweden | Independent ERP consultant |

### *3.1 Interview guide and cases*

The interview guide was developed by the authors in order to gather insights about the topic understudy. The authors used constructs from the existing body of knowledge on CRM, ERP, and ERP II, plus their practical experience as basis for the questionnaire development. The questionnaire covered several topics, including reasons and motivations for CRM adoptions, capabilities of the CRM vs. ERP´s CRM modules, challenges with current ERP and the CRM-related activities, CRM and ERP integration plans, and implementation costs. Moreover, we also asked about the status of ERP II from the points of view of our informants. In a column to the right of the questions, potential follow-up questions were listed. A sample of the pool of questions is presented below:

- What were the organization’s motivations for investing in an ERP system?
- What were the organization’s motivations for investing in a separate CRM system?
- Did you consider acquiring a single ERP II system instead of investing in multiple systems? Why/why not?
- In your opinion, what are the main challenges for implementing an ERP II solution?
- Is your ERP system integrated with the CRM system?
- Do you have other standalone systems (e.g. e-commerce platforms)?
- Are you planning on replacing your existing systems with ERP II solution in the near future? Why/why not?

Because of the adoption of an interview guide, there existed some systematic controls during the interviews [41]. The interview guide was sent to other peers in order to get feedback on the questions and clarity of the guide. Some important feedback was received about the vagueness of some questions, which were then enhanced. Later, the interview guide was again revised and enhanced after the first two interviews. The revision contained some rewording to some questions and also a change in the order of some questions, as the researchers learned what was more natural to ask consecutively during the interviews. More information about the target organizations is provided below.

**Organization 1** is an international bank’s branch located in Norway. The bank is a large bank with more than 20,000 employees worldwide. The bank operates in several countries around the world. Organization 1 offers offline and online banking services to its customers. The bank has a B2B platform available for its business customers. In addition to SAP ERP, the branch has a separate on-premise CRM system, and is currently in the process of evaluating other cloud-based CRM systems.

**Organization 2** is a small consulting firm in the United Kingdom. The organization has ca. 30 employees and operates in several countries around Europe. The organization has various systems including ERP, CRM, plus a specialized lead-generation software. The organization operates in the area of business consulting focusing on aiding start-ups in establishing their businesses. The company implemented an Oracle ERP in 2015. Besides the ERP, the organization recently implemented a CRM system. In addition, the organization uses a specialized application that aids the sales team to easily find information on the Internet for lead-generation purposes. This application is separate from the CRM system.

**Organization 3** is a consulting company, located in Austria, which supports IT companies in the EMEA region by increasing their revenue in their indirect sales channels. Their main clients are market leaders in their industry. The company has approximately 35 employees, plus a network of approximately 20 independent partners (freelancers). It was founded in 2007 and implemented its first ERP System, SAP BusinessOne, in 2009. The system experienced a major upgrade to the latest available version then, in 2014. The decision to implement a CRM system was taken in 2015, after the company had used SharePoint and Excel Sheets to administrate their leads. The organization decided to use HubSpot CRM, a system provided by the US-based company HubSpot, which besides sales also offers solutions for marketing activities. The CRM system is free of charge, but has chargeable add-ons, especially in the area of advanced reporting and marketing. At the time of writing this paper, no add-ons have been acquired by the case organization.

**Organization 4** is a large Norwegian company working in the area of building information management (BIM) for construction companies. The interviewee is an IT applications consultant and has around 20 years of experience in sales and 10 years of experience with digital business systems in the role of a product owner. The current position is described to be the bridge between the product owners of their many systems and the developers. The interviewee has in-depth experience with CRM systems since almost 20 years. The organization has a Visma ERP system, and Super office CRM system. Both are local Norwegian systems.

**Organization 5** is a Norwegian company within the industry of manufacturing functional clothing. Originally founded as a start-up in Oslo few years ago, the company now has retailers in all Scandinavia, UK, US, Netherlands, Germany, Austria and Switzerland. We have conducted an interview with the Sales Manager, which was involved during the ERP and CRM implementations that the company had earlier. Currently, the organization has a Norwegian financial system (Tripletex) that has a CRM module.

**Organization 6** is a retailer that deals with a various number of products, which are sold directly to customers through two outlets. The company has been established in 2005 in Cairo and is now one of the largest supermarket chains in Egypt. The organization is considered a large enterprise, and its current workforce consists of more than 2,500 employees. The retailing commodities vary from fresh food, fast moving goods, non-food commodities, textiles, and furniture. The company production mainly focuses on food manufacturing and packaging. Prior to the current ERP adoption, they had a previous Oracle JD Edwards ERP and the implemented modules were FC, Capital Asset Management, Manufacturing, Logistics, Procurement, and Sales & Distribution. The ERP went live in August 2007, and another upgrade was done in 2012. Recently, the organization has retired its Oracle JDE ERP and replaced it with SAP A1 ERP. The system went live in the mid of April 2017. The organization has also implemented an open-source CRM system (SugarCRM). We have conducted one interview with a senior ERP consultant that has been involved during the ERP and CRM adoption decisions, selection and implementations.

**Organization 7** is one of the largest Telecom operators in Egypt. The organization has several systems and had several ERP implementations before. Currently, Organization 7 has an SAP A1 ERP and an on-premise Microsoft Dynamics CRM. We have conducted interviews with two personnel from the marketing and sales department. Both employees were key users during the ERP and CRM implementation projects.

**Organization 8** is a Nordic bank located in Norway. The bank has presence in more than 15 countries worldwide, with more than 30,000 employees. Organization 8 offers offline and online banking services to its customers. In addition, the target organization offers open APIs (application programming interfaces) to its customers, in order to enable the integration of the customers' ERP systems with the bank's ERP to facilitate seamless B2B electronic transactions. The branch has a separate in-house developed CRM system, and an SAP A1 ERP.

**Imp. partner 1** is a multinational organization and one of the largest ERP implementation partners and consulting firms in the Czech Republic. The organization implements several ERP systems including SAP and Oracle ERP systems. We have interviewed one of the senior SAP ERP consultants, which has been involved in several large implementations around Europe.

**Imp. partner 2** is a small implementation partner and ERP reseller located in Alexandria and Cairo in Egypt. The case organization is specialized in implementing ERP systems and providing enterprise security solutions. The company operates in Egypt and the middle-east region in general. The organization mainly implements two international ERP packages. The ERP systems are Indian and Turkish packages. Both systems provide localized packages in Arabic for the Egyptian market. We have interviewed a junior ERP consultant that has been involved in few ERP implementations involving the Turkish ERP.

**V** is a local Egyptian vendor. The vendor provides an ERP system that targets medium to large organizations. The ERP can only be implemented on-premise; however, the organization is currently working on the cloud-based version. We have conducted two interviews with the organization's general manager and a senior consultant.

**Cons 1** is an Oslo-based freelance and independent Enterprise Systems consultant that have been involved in more than twenty ERP and CRM implementations in several regions of the world. The consultant has also extensive experience with open-source ERP and CRM systems. In most of the ERP implementations, the consultant was mainly responsible for the sales and distribution of CRM modules.

**Cons 2** is an independent Enterprise Systems consultant located in Sweden. The consultant has more than 20 years of consultancy experience with enterprise systems and data mining projects. The consultant has also been serving as a systems selection consultant for several international organizations with various sizes.

### *3.2 Sampling and data collection*

The selection of target cases was completed through purposeful and snowball sampling methods [37]. First a small group of initial informants in organisations that have both a CRM and ERP system were identified. These potential informants were then contacted via phone and e-mail for interview requests. Some of the potential informants agreed to be interviewed, and others suggested other peers with more sufficient and relevant overview on the research topic. In addition, some informants suggested other target organisations which qualify for the research context. The target cases were therefore not preselected in this study. All interviews took between ca. 30 to 50 minutes. Fourteen of these were face-to-face interviews, and two interviews were conducted over the phone. All the interviews in the target cases were digitally recorded, and carried out with employees, which had deep knowledge about the technology (ERP & CRM) and the CRM related processes. In addition, all the interviews were conducted at organizations that have ERP with a CRM module, or/and CRM systems. Four interviews were conducted in Arabic language, one in German, and the rest were conducted in English. All the Arabic and German interviews were translated, and all the interviews were then transcribed.

It is important as researchers to envisage how many interviews are enough to reach data saturation. Data saturation is reached when the aptitude to gather additional new information is limited [42]. Thus, it is imperative to reach data saturation, as it directly impacts the content quality and validity [42]. The researchers experienced data saturation after the first five interviews in target organisations, that was confirmed when the remaining interviews were not yielding additional significant information. Therefore, recruiting more informants from user-organisations was deemed unnecessary, however, in order to have more insights over the research topic, informants from consulting and vendor organisations were then recruited.

The data gathering process was conducted over a period of ca. one year and a half. Two iterations of interviews were conducted. The first two interviews were the first pilot iteration. The reason for these two pilot interviews were conducted to enable the opportunity to listen to the interviews and evaluate in the first iteration in order to improve the interview guide if necessary, before conducting the rest of interviews. The data gathered represented the personal insights and opinions of the informants from the various stakeholders who represent the user, consulting, and vendor organizations.

### *3.3 Data and cross-case analysis*

Data analysis and specifically cross-case analysis should preferably be used when searching for patterns among the various cases [43]. These patterns can be mainly identified by using three methods: a) the selection of categories and scanning for within-group similarities coupled with intergroup differences, b) the selection of pairs of cases and listing of the similarities and contrasts between each pair, and c) the classifying of data by data source to extract distinctive understandings from different types of data collection [43]. After the data collection process was completed, the data had to be electronically organized in order to be ready for analysis. Hence, the authors independently used colour coding [44] and tagging techniques, whereby the data gathered in each interview was classified according to the topic of discussion, and according to the question and interview guide's part in which it is situated. In addition, the authors also added notes, comments, and interpretations on some data segments. It was then possible to generate matrices, which can be classified by topic, interview, and/or case. This process eased the data analysis, because it enabled the authors to view the data related to the focus and theme per question and per interview. The colour coding system aided in visualising and the identification of patterns across the data.

With regard to the data analysis, several topics emerged during the discussions with informants in the interviews. Across all cases, data was usually analysed on the basis of topic and focus. For example, extracting the data from interviews that are related to challenges with using ERP system's CRM modules. In some other cases, the theme in the data collected has emerged, which is natural in semi-structured interview setting. Thus, two coding strategies were applied in this study. These can be classified as selective and theoretical coding [45], in which the categories were predefined and coded, and in other cases they were grounded and emerging from the data.

## 4. Results and Discussion

Based on the interviews and the findings, we were able to identify five main constructs that explain why our case organizations invested in separate CRM systems: scoping during ERP acquisition, costs, user-friendliness and ease of use, and the specialization on CRM-related processes (see figure 3).

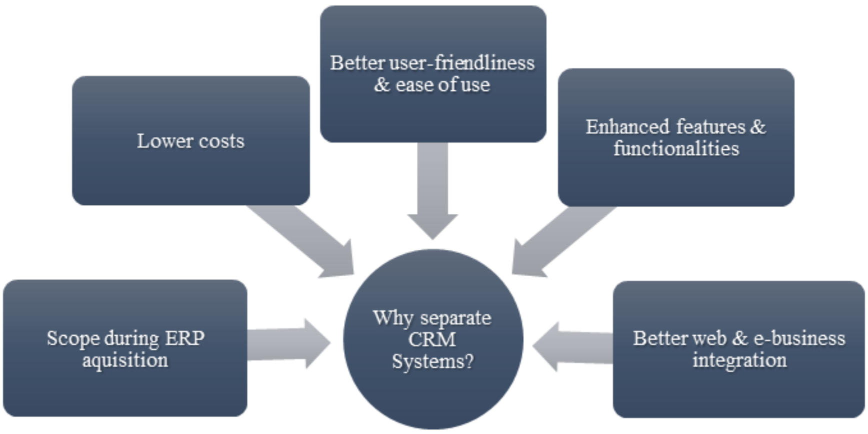


Fig. 3. Overview of results.

### *4.1 Scope during ERP acquisition*

In many cases, organizations either start with an ERP implementation first and then implement a CRM system at a later stage, or vice versa. It rarely happens that an organization would implement both simultaneously. While several of our informants stated that they would have gone for a separate CRM system anyway, some also mentioned that they didn't think about it during the ERP selection for several reasons. "Both systems are huge and require a lot of resources during implementations, and it is almost impossible to work on both projects in parallel, as they also have different focus." (Marketing manager, Organization 2). Another informant added, "the company did not really think about the CRM solution when they chose their ERP system. The ERP system had to be SAP, which was a requirement by the CEO, and the company only had eight employees at that time." (Head of sales, Organization 3). Some also related to this state because of the complexity of the project scoping. "While we knew that we need a CRM system/module, still CRM as such was beyond our scope during the ERP selection phase. There are many factors that play a role on the chosen ERP and these factors suppress the CRM selection, which has to be looked at in a separate and later phase." (Sales employee, Organization 7). "It is very difficult to implement both systems in one shot, the ERP alone is considered a large milestone". (Senior consultant, V). In addition, at the time of the ERP selection, customer relationship was in an early phase at some of the organizations, "sales was done mainly by using the former professional network of the company's founder, no one really made strategic sales in the beginning, so we didn't really consider a CRM back then [...], however, due to the unforeseeable growth and the importance of sales that came along with the growth, a different ERP solution with a proper CRM module from the beginning could potentially have saved the parallel construction." (Head of sales, Organization 3).

One of the senior informants (Senior consultant, Organization 6) mentioned that organizations tend to go for a separate CRM solution anyway, "based on my experience, regardless of which ERP they have, the majority of companies go for a separate CRM system". Likewise, one of the independent consultants confirms this view, "Usually organization go for the two separate solutions, as it is very complex to combine both in the same project [...], even if the ERP systems has an established sales & distribution module, or even a complete CRM module, organization usually prefer to buy best-of-breed in both areas." (Cons 1). Another reason for this separation could be related to the different focus of each system, "The ERP is more of an internal system, SCM and CRM cross the boundaries of the firm, they are very different in scope." (Senior consultant, Organization 6).

### *4.2 Costs*

While the majority of our case organizations have on-premise ERP systems, several of them went for a cloud-based CRM solution. In addition, several of the interviewees from the implementation partners, consultants, and vendors mentioned that the majority of their clients prefer a cloud-based CRM, but not a cloud-based ERP. This could be related to the following statement: "In our organization, one of the reasons for adopting a separate CRM was the cloud option. Our ERP is on-premise for several reasons, but we wanted a cloud CRM, thus we went for Salesforce." (Senior consultant, Imp. partner 2). The arguments for cloud-based CRM systems are several, like availability and leveraging the systems administration to the vendor. One of the ERP vendors we have interviewed also has a cloud-based CRM, "yes, we have chosen Salesforce because it is cloud-based and available 24/7 with less administration efforts from our side." (Junior consultant, Imp. partner 2). On the other hand, several other informants mentioned that the overall costs of having a cloud CRM could be less than running a CRM module in the ERP system. "The current ERP system is an on-premise solution and only 8 licenses had been acquired, which was mainly used by accounting and people from the operations department. The organization evaluated to purchase additional licenses for the sales staff, however decided to not purchase them, as the cost was comparably high", (Head of sales, Organization 3). Likewise, the marketing employee at Organization 3 argued for the cost savings from a cloud-based CRM, "beside the high cost for CRM users on the ERP system, also the low costs of the new solution had an effect on the decision, in both technical and consulting costs [...], the CRM was ready to be used after 5 clicks and came with an out-of-the-box sales funnel which could be used almost right away. […] The fact that the CRM is in the cloud and that we therefore did not have to invest in architecture and server and so on, was definitely a main argument for us." Another informant also compared on-premise ERP and CRM systems, "the ERP systems are so monstrous, they have so many functionalities, so you need a specialist or somebody educated to be able to handle and adjust these systems, so it will be really expensive for the company, because you maybe need a full-time consultant for I don't know how long to just adjust the system, and if you want to do something you have to pay this consultant again and again for each time you want to do some changes and customization [...], cost is always an issue, and actually I think we save money by having another separate CRM system" (IT application consultant, Organization 4). In addition, informant at Imp. partner 1 elaborated on why they went for a cloud-based CRM system and was asked about how important costs are for his company, he stated "very important, even though it's a huge company", (Senior SAP consultant, Imp. partner 1). On the other hand, other informants from large organizations mentioned that CRM systems, in cloud or on-premise, cost less in general, "separate CRM systems cost less in various ways, from training, learning time, consulting, maintenance, and errors-related costs." (Sales employee, Organization 7), "to buy 7000+ licenses from our ERP system vendor to use its CRM is very costly for us." (Senior business support employee, Organization 8).

### *4.3 User-friendliness and ease of use*

Almost unanimously, our informants stated that specialized CRM systems' interfaces are by far more user-friendly than sales and marketing related modules or CRM modules in well-known ERP systems. "Current CRM systems in the market have very easy to use and learn interfaces, which take very little time for sales and marketing people to be able to use them efficiently", (Independent consultant, Cons 1). Other informants also mentioned that user-friendliness was one of the major reasons for acquiring a separate CRM system. For example, the head of sales at Organization 3 mentioned that the main features (administration of leads and opportunities) are similar in both solutions [ERP & CRM], however, the new CRM solution seems to be much easier to use, more intuitive and accessible from everywhere, and the data entry, therefore, is supposed to go fast and uncomplicated as the interviewees stated "This (user-friendliness) was a major, major, major reason! […] I didn't want it to be complicated." (Head of sales, Organization 3). "You can move things forward and backward in the CRM system […], but at the ERP system it is not that easy." (Marketing employee, Organization 3). One informant mentioned that some ERP systems have user-friendly CRM modules, however, still they are not as good as the modern CRM system interfaces, in his point of view, "I have seen very nice CRM modules in specifically some open-source ERP systems, however, they can't compete with specialized CRM systems." (Independent consultant, Cons 1). This view has been confirmed with another informant, "Salesforce and Soho and similar online-based systems are growing fast because they are easy to use, have easy to install plugins, and if you need extra functionality you can just add it and it will just work." (IT application consultant, Organization 4). "If a report needs change and new fields need to be added, every administration user can do the changes. Even though the system itself is free of charge, chargeable add-ons are available." (Head of sales, Organization 3). One of the ERP vendor's informants also confirmed this belief, "due to their smaller scale, specialized CRM systems are more intuitive and easier to use than ERP systems. If the ERP has the same process you want to do on a CRM system, it will be much easier to do it on the CRM." (General manager, V).

### *4.4 Features and Functionalities*

While the main features and functionalities between CRM systems and CRM modules in ERPs are very similar, but by nature, CRM systems have a clearer focus on customer relationship related functionalities. Some features are only offered through CRM systems and this evidently had a strong effect on the decision to adopt a separate CRM system at our target cases.

Some of our informants stated that they went for a separate CRM solution, as the current sales and distribution module in the ERP is not sufficient. "We implemented SugarCRM as it is easily and fully integrated with our call centre system." (Senior consultant, Organization 6), "it was relatively easy to integrate our CRM system with the tele-sales system." (Senior business support employee, Organization 8). In addition, other informants stated that the current CRM-related modules in ERP systems are not really covering the whole sales or marketing full cycles. "It is not easy to create a campaign, assign a team, manage the team, and follow-up on the campaign in ERP systems, if they have these features in first place." (Marketing employee, Organization 7). Likewise, "Current ERP systems lack the full sales and marketing cycles, for example, it is not possible to monitor and measure the customers' churn rate, retention, happiness factors, and customer experience." (Senior consultant, Organization 6). Regarding the features of CRM systems, the marketing employee at Organization 3 mentioned that, "The CRM system offers us a lot of things that we haven't even explored yet, you can send e-mails and even call customers through the system… something that our ERP might never offer us". "There are many details and workflows not existing in the ERP and cannot be traced, and most of them are non-financial transactions, including marketing, presales, after sales support and warranty". (Junior consultant, Imp. partner 2). Similarly, the Marketing employee at Organization 1 mentioned that "the CRM module in our ERP was considered very restrictive in comparison to our separate CRM application”. In addition, one independent consultant stated that some ERP systems lack competence in their CRM solutions and modules, “several ERP systems have lousy CRM modules and lack core functionalities that sales, marketing, and customer service teams need. By the way, this is not restricted to CRM modules, for example, some years back, several organizations which I served as a consultant for, implemented separate human resource management systems instead of using the HRM module from SAP, as they have seen it as mediocre module, however, this is not the case anymore as this module has been totally enhanced after the acquisition of the SuccessFactors resource management systems by SAP.” (Cons 2).

Since the CRM solution at Organization 3 is cloud-based, the system is available and accessible from everywhere and apps can be used on mobile devices to track activities, which makes it particularly attractive for the organization, “we actually liked the thought of having something that could be accessible everywhere. And then you look at all the add-ons that you can do with HubSpot […], you can even use it on your phone.” (Head of sales, Organization 3). The same informant mentioned that if ERP systems’ related CRM modules were comparably good with CRM systems, they would have gone for the one solution (ERP), “costs were definitely an argument, but if the (existing) ERP system had 10 times better features, we would, for sure, have bought additional licenses”, (Head of sales, Organization 3).

### *4.5 Better integration with web and e-business platforms*

Our main findings suggest that ERP systems of today are far from replacing e-commerce and e-business platforms. When our informants have been asked regarding this possibility, they have stated that this not attainable yet. “For sure our ERP system cannot replace the adoption of e-business platforms. We need sometimes several systems to act as our front and back-ends to our e-business platform.” (Customer service employee, Organization 1). “In my experience, I did not see any ERP that is capable of replacing e-commerce and e-business platforms, not even decent store fronts. They definitely can be integrated with these infrastructures but will not provide all the functionalities that are usually needed by the marketing and sales teams.” (Cons 1).

One of the main features of established and specialized CRM systems is the ease of integration with online and e-business platforms. For example, CRM systems facilitate the seamless integration with web marketing tools and landing pages of the companies’, in order to potentially transfer a prospect into a lead, as stated by one of the interviewees: “When we implemented the ERP system, it was crucial to us to not only cover lead management, but also to administer lead generation and nurturing. […], in other words, we needed a system that could track when someone downloads a whitepaper from our website, a cold-lead so-to-speak, so that we could follow-up on their downloads and offer them our products. […], the combination of who downloaded, what, and when, and to be able to sell them something based on that, we simply didn’t find that feature in our ERP.” (Marketing employee, Organization 3). Also, the flexibility and the ability of CRM systems to integrate and import data in several formats are considered paramount advantages, “you can import contacts, you can import leads from *‘XLS’* files or you can have automated leads from Internet directly into your CRM system. So, all these specialized functionalities are for me the basic reason why organizations chose to have a separate CRM system.” (IT application consultant, Organization 4). Our informant from Organization 2 have expressed the difficulty of having the ERP system integrated with their website, “it can be integrated with our website, which is a lot of work, but it can’t replace our need for online and e-business platforms”. Correspondingly, another interviewee mentioned that the CRM module in ERP systems are troublesome to integrate with e-business platforms, “we have a complex e-business web portal that we provide to our business customers, which in part is connected to our ERP system, however, our CRM provides more control on monitoring the online platform and provides better tracking and reporting capabilities.” (Customer service employee, Organization 1).

## 5. Conclusions and Future Research

ERP systems have, no doubt, matured greatly since they were first introduced. Most of the current systems provide several modules that could virtually cover all the needs and business functions in organizations. Modern ERP systems also provide several enterprise application integration solutions through APIs or service-oriented architecture platforms. This partially corresponds to Gartner’s vision of ERP II, which projected how ERP II will replace almost all organizational and cross-organizational systems. While earlier research suggested that by now (e.g. 2020) ERP II systems will be available, however, this vision seems to be non-realistic and difficult to attain. Via conducting interviews with clients, consultants, vendors, and implementation partners, we have attempted to elucidate their perspectives and opinions on why ERP II is not a standard yet. Our informants believe that the existing ERP systems are definitely more flexible and integration-ready than their predecessor versions, but still non-replacing for specialized systems like CRM, e-business platforms, or specialized SCM systems. In addition, it could be more economically feasible for enterprises to implement separate best-of-breed systems instead of one large system at once. This could be due to the fact that some of our target organizations prefer to have on-premise ERP and in-cloud CRM systems, or because of the better user-friendliness and features of specialized CRM systems. In addition, several informants mentioned that training, consulting, maintenance, and license costs related to CRM systems are dramatically lower than ERP counterparts, especially if the CRM is cloud-based. Moreover, the difference in project scope, focus (internal & external) and motivations between CRM and ERP systems make it troublesome and complex to implement both simultaneously. Also, the results show that the vision of having one ERP II system implementation at an organization could be severely difficult and complex to manage, which goes in-line with what has been suggested in earlier literature. Current ERP systems are mainly lacking the full sales and marketing cycles, and also, they lack several other important needed features, special reports and forecasts. Interestingly, all of our cases did not integrate their ERP and CRM systems *(yet)* process-wise, and some informants even argued that they do not see the process integration between CRM and ERP systems as a needed effort, as they have different scopes, purposes and targets within organizations. Having said that, most of the case organizations either integrate both systems on a data-level or use data mapping techniques to enable analysing the merged data from their ERP and CRM systems. In brief, the systems are coupled data wise, uncoupled process wise. In addition, one independent consultant informant stated that ERP vendors nowadays have a different approach from the earlier ERP II vision. This means that the current vendors focus further on providing more flexible and open systems that are ready for integrations with other systems (e.g. via SOA platforms), rather than building comprehensive systems that attempt to replace other enterprise systems.

Our study implies at least five suggestions for future research. Firstly, more research is needed on the viability of ERP II systems in other industries or contexts than the ones covered in this study. Secondly, more research is needed on how vendors envision the future of ERP systems and the idea of ‘one-system-fits-and-covers-all’. Thirdly, ERP vendors should work together with their customers to understand the needed features from the future ERP systems. Fourthly, researchers need to explore the process integration benefits between CRM and ERP systems, as our results suggest that some organizations view it as an unfeasible project. And finally, researchers and practitioners need to explore the topic of how ERP systems can replace e-business platforms, or at least ease their integration, which our findings suggest that they have failed in fulfilling this vision until now.

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# Project portfolio risk management: a structured literature review with future directions for research

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**Abstract:**
Project Portfolio Risk Management (PPRM) has been identified as a relevant area regarding project portfolio success. This paper reports on a structured literature review of PPRM. A structured search and selection process was carried out and conventional content analysis was conducted in the literature analysis of 62 papers published in international journals. PPRM has its theoretical and practical bases in the modern theory of portfolios, decision theory and risk management (RM). The content analysis reveals four main recurrent topics in PPRM: (1) The influence of RM on project portfolio success, based on project portfolio impact level, moderators or contingency factors between RM and project portfolio success, and PPRM dimensions; (2) risk and project interdependencies, highlighting resources, technology, outcome, value, and accomplishment project interdependencies; (3) project portfolio risk (PPR) identification, where four main risk source categories are identified; and (4) PPR assessment, composed of risk measures and the main methods used for risk assessment. Therefore, this study provides an overview of PPRM as a research field, while it also promotes four future research directions: (1) PPRM as part of organizational RM; (2) RM, success dimensions and strategic impact; (3) mechanisms for PPR assessment, and (4) PPRM as a complex and dynamic system.

**Keywords:**
project portfolio management; project portfolio risk management; structured literature review; research opportunities.

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## 1. Introduction

Project Management (PM) has gained increasingly more attention in organizations, generating a greater allocation of human and financial resources, organizing work into projects, increasing the number of projects to be implemented and establishing a relationship between projects and the organization's strategy, as well as expanding the scope and complexity of PM [1]. In this context, Project Portfolio Management (PPM) emerged, representing the coordinated management of a set of projects carried out by a specific organization, which allows for strategic management of the projects, throughout which scarce resources are balanced, and for guiding the portfolio to achieve strategic benefits [2-5]. Nevertheless, the positive impacts in the organization may not be as expected due to project and portfolio risk effects [6]. Therefore, one key area for PPM is risk management (RM) [7, 8].

The literature shows that managing risks only at the level of projects is not sufficient because a strategic and holistic view of risk is not considered [9, 10]. It does not include other important considerations about RM in its own project portfolio environment [6, 7, 10], or the effect generated by the interdependencies between projects and between risks [9, 11]. Project portfolio risk has been studied from different perspectives, for example from project portfolio selection with risk considerations[12, 13] and from project portfolio execution [9], as well as from the point of view of project portfolios in project-based companies, such as technology information portfolios [14-16], oil and gas production portfolios [17] and construction project portfolios [18]. It has also been studied from the perspective of project portfolios associated with organizational strategic development or generic portfolios [7, 12, 19, 20]. The above evidences that RM applied to project portfolio decisions is of interest and relevance for the different types of project portfolios identified in organizations.

Thus, a body of literature concerning Project Portfolio Risk Management (PPRM) has been generated, providing knowledge and understanding about objectives, features, and the impacts of PPRM. In this regard, a structured analysis of the literature would allow an overview of the current state of PPRM to be obtained, and a systematic classification of the progress to be made in acquiring knowledge in the PPRM field, thus contributing to a better understanding of the current issues and to the identification of the possible future research opportunities open to PPR researchers. Therefore, this research intends to contribute towards outlining PPRM as a research field, for which two research questions were formulated: (1) What are the main topics and debates in the literature on PPRM? (2) How can future research expand the PPRM research area? A structured review of the literature on PPRM was carried out and Content Analysis (CA) was conducted in order to answer the research questions. While it is recognized that projects, programs and portfolios are interrelated [21, 22], the scope of this literature review was limited only to RM applied to project portfolios.

The remainder of the paper is organized as follows. Section 2 presents the PPRM conceptualization adopted in this research study. In Section 3, the methodology used in the literature search and analysis process are reported. The findings are described in Sections 4 and 5. Section 4 presents analysis of the 62 papers that met the inclusion criteria, which lead on to a description of four recurrent topics identified in the literature on PPRM, while in Section 5 future directions for research are identified and described. Finally, the conclusions are summarized in Section 6.

## 2. Project portfolio risk management conceptualization

A project portfolio is a collection of single projects and programs that are carried out in an integrated way, through which an organization seeks to achieve its strategic objectives, by managing the interfaces between projects and balancing scarce resources across projects and programs, as well as risks and benefits [7, 23]. In this regard, Bathallath et al. [24] highlight the importance of project interdependency management in the success of project portfolios. From a PPM process perspective, three generic, interdependent and recursive main phases are described in the literature [25, 26]: portfolio structuring, resource management and portfolio steering. Portfolio structuring is associated with strategic planning cycles, which include portfolio planning, and the selection of projects according to the organization's strategy. Resource management implies resource allocation across projects, with the resource management carried out in an integrated way. Portfolio steering comprises a permanent execution and coordination of the portfolio, monitoring the different aspects defined as key aspects for each portfolio.

Establishing the difference between the concepts of risk and uncertainty is of the greatest importance because this determines the RM scope, as well as defining the characteristics of the risk assessment and the design of response strategies [7, 11, 14, 27]. Different risk perspectives have been identified in the project portfolio context: a first perspective proposes that the variability that can be quantified in terms of probabilities is considered as risk, while the variability that cannot be quantified at all is best thought of as uncertainty [28]. In this perspective, risk and uncertainty represent outcomes. A second perspective proposes that all uncertainty components can be measured and split in three components: insignificant events (events without major effects on the project portfolio), positive events, and risk events, where the latter are those that can threaten project portfolio success [11]. A third perspective proposes risk as a consequence of uncertainty, this approach being quite popular [7]. This third perspective has been widely used in project portfolio selection with risk considerations, where the uncertainty is represented using stochastic variables. These denote the inputs, while the risk is the output that represents the extent to which the expected results are affected as a consequence of the behavior of the inputs [29–32]. In all the approaches identified, the risk is characterized by its measurable attributes, such as probability distribution, occurrence likelihood or impact [11, 20, 33].

RM is concerned with how decision-makers define the type and level of risks that they consider appropriate for each decision at each time. RM is, therefore, focused on how to make choices concerning risks, considering the possible reward and its possibility of success by means of managing people, processes, data, and projects [28, 34]. In this regard, previous studies show the limitations of the traditional RM approach, since it is oriented to individual projects, ignoring the integration levels and the interaction of information, while the domain of PPRM allows RM activities to be consolidated, thus avoiding a duplication of effort and resources [6, 7, 9]. The origins of PPRM can be traced to the works of Markowitz [35]. Hofman et al. [7], Sanchez and Robert [36], and Teller [27], among others, has identified PPRM as one of the fundamental areas of work and research in PPM, and as a fundamental topic in relation to project portfolio success.

Consequently, this research has adopted the perspective that PPRM must focus, among other things, on the identification and balance of the risks of the project portfolio, while seeking to maximize the value delivered to the company, reflected in the impact achieved on strategic goals. As such, PPRM must focus on reducing negative risk impacts and potentializing opportunities, while considering and evaluating the interdependencies among risks and among projects, as well as the management capabilities of the organization [7, 9, 11, 37].

## 3. Methodology

### *3.1 Research design*

This study follows a structured literature review process. In the PM field, structured literature reviews have been adopted, among others, by Araújo et al. [38], Laursen and Svejvig [39], and Miterev et al. [40]. Svejvig and Andersen [41] summarized the literature review process in five steps: planning and scope definition; conceptualization of topic; searching, evaluating, and selecting literature; literature analysis; and report and disseminate. Fig. 1 summarizes the literature review process.

### *3.2 Data collection*

In the *planning and scope definition step*, it was defined that only articles published in scientific journals would be considered. According to Rowley and Slack [42], in professional disciplines, articles in scholarly and research journals should form the core of the literature review, since this literature source has been peer-refereed prior to acceptance for publication, and contains critical treatment of concepts and models. The articles selected should include PPRM as their main topic or, if the main topic is not PPRM, their main objective should show a specific and explicit relationship with PPRM. It was also defined that the literature search would be carried out using the SCOPUS and Web of Science -WoS- databases, given that they cover a wide range of peer-reviewed and high quality scientific journals.

Some publications, such as Hällgren [43] and Söderlund [44], carried out their literature review process based, respectively, on the most relevant journals related to project management and on management and organization journals outside the conventional project management publications. However, and similarly to Laursen and Svejvig [39], the literature review carried out in this study had the goal of including a wider range of publications related to PPRM, and therefore the scope of the search process was not restricted to specific journals.

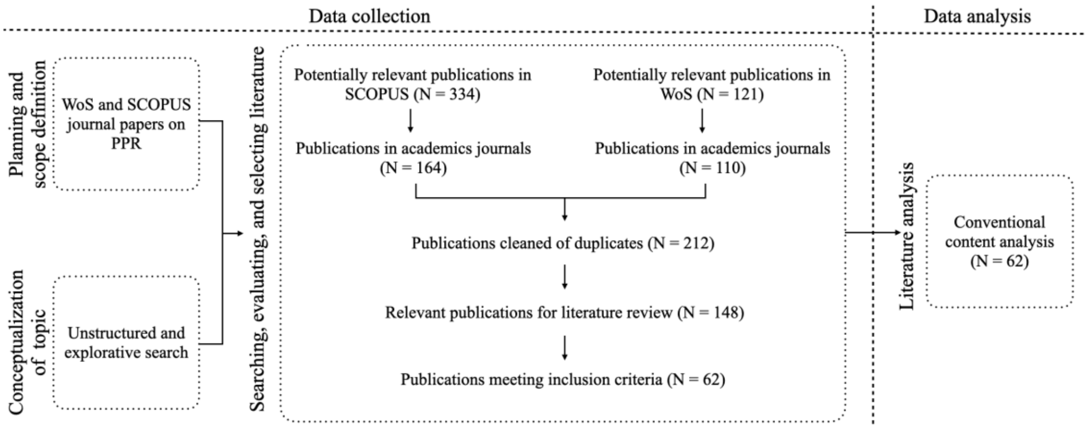


Fig. 1. Structured literature review

The second step is associated with *conceptualization of topic*, for which RM, PPM, and PPRM were conceptualized as key concepts, as well as the risk and uncertainty approaches in the PPRM context. Project portfolio selection with risk considerations is a research topic that has seen important developments and it represents the beginning of RM being applied to project portfolio decisions, with Markowitz' work seminal in the area [28]. The main publications used specifically to conceptualize the PPRM topic were: [2, 7, 9, 45-47].

*Selecting literature* corresponds to the third step. Based on the contextualization of the topic, it was defined that, for papers related to PPR applied to portfolio execution, in its function as an emergent topic [6, 7, 9, 27], the year filter would not be applied. Although, for project portfolio selection with risk considerations, the year filter selected was 2015 onwards (up to the end of December 2018), since this is a topic with a large number of publications, and according to Dobrovolskiene and Tamošiuniene [48] earlier works are generally included in the latest research. The keywords identified as part of the conceptualization of topic were used in an iterative evaluation of different search strings. The string search that best grouped the publications on PPRM was "project portfolio" and "risk" in the categories of keywords, title and abstract.

349 works that met the search equation used were identified in SCOPUS and 121 in WoS. Selecting only words published in academic journals and discarding paper duplicates between databases, 212 publications were identified. Applying the year constraint defined in the *planning and scope definition* step (2015 - 2018) for project portfolio selection with risk consideration publications, coupled with the abstract and introduction section reading of the papers selected, 62 papers were selected for the literature analysis process (30 related to project portfolio selection with risk considerations and 32 associated with PPR applied to project portfolio execution). Table 1 presents the five journals in which more than one paper was selected, representing a total of 18 of the 62 papers selected for this study.

The remaining 44 papers were each published in a different journal, such as 'Operations research', 'Omega (United Kingdom)', 'Production and operations management' or 'International journal of fuzzy systems', among others. The publications selected are identified with the character '*' in the list of references.

Table 1. Journals in which more than one paper published

| Journal | Number of publications |
|---|---|
| Project Management journal | 6 |
| International Journal of Project Management | 5 |
| Sustainability (Switzerland) | 3 |
| International Journal of Managing Projects in Business | 2 |
| International Journal of Information Systems and Project Management | 2 |
| International Journal of Project Organisation and Management | 2 |

### *3.3 Data analysis*

Literature analysis was based on CA. CA allows for the interpretation of the meaning or usage of written data, organizing information into relevant categories for each specific research work, and establishing an understanding of the topic being studied [49, 50]. Three main approaches can be used to conduct CA: conventional, summative, or directed [49]. Summative CA is the most quantitative approach, seeking as it does to explore the contextual use of words, and the findings may be explained using descriptive statistics associated with the frequency of use of particular words or phrases in specific contexts. Directed CA requires that data codes and categories be defined in order to apply them deductively to code the data; as a fundamental purpose, it adds credibility to a theoretical framework or conceptually extends a theory. Conventional CA "provides a much more comprehensive picture of the phenomenon, through new insights exclusively grounded in the data, than the other two types" [49, p. 830].

In this regard, conventional CA was implemented for the literature analysis reported in this paper. Conventional CA is the most inductive type of CA, it being a descriptive approach [49]. In this approach preconceived categories are not defined; conversely, categories and new insights emerge from critical and reflexive analysis [49, 50]. In order to identify recurrent overarching topics and future directions, a sequential cumulative process was implemented. The literature analysis was based on a chronological analysis of the publications (from oldest published papers to most recent papers), and, for each analyzed publication, one or more preliminary categories and subcategories associated to current topics and related to future directions were identified.

To the extent that publications were analyzed, the categories identified (both recurrent topics in PPRM and future directions of PPRM) from each paper were contrasted among categories identified in the publications analyzed previously, defining a preliminary set of categories and their composition and attributes. To carry out this analytic process, a set of five papers were analyzed for each analysis cycle, and, once the preliminary categories were established, a new analysis cycle was carried out based on the next five papers.

As part of the literature analysis cycles, sometimes it was necessary to re-analyze some papers previously analyzed, in order to confirm, extend, or redefine the information established from those papers regarding the possible new categorization structure. Thus, as publication analysis progressed, it was necessary to define, add, merge, divide, or reconstruct the categories or the subcategories in accordance with the new information obtained from each newly analyzed publication, forthwith until a final categorization was reached.

Once a final categorization had been defined, the information regarding subcategories was analyzed in order to obtain a consolidated description of each general category, both regarding recurrent topics in PPRM and future directions of PPRM. The results concerning recurrent topics and future directions are shown in sections 4 and 5 respectively, in which each final established category corresponds to one subsection of each section.

In order to define the categories regarding recurrent topics in PPRM, for each publication the following issues were analyzed: the general problem that framed each study, the specific research question or research objective documented, and the background reported. Then, the method, approach, or methodology developed or applied and the results of each study were analyzed, on the one hand, regarding the respective research objective, and, on the other hand, regarding a general perspective of PPRM as a research field.

To complement this, the analysis carried out regarding the general problem and the specific research question or research objective became an input for the identification of future directions. Thus, general research problems identified and RM requirements were contrasted with the results described in each paper analyzed, in order to identify and consolidate the future directions of PPRM. So, based on that information, a specific analysis of the limitations, assumptions, conclusions, or future directions reported by each publication or identified as part of the paper analysis, was carried out.

## 4. Analysis of project portfolio risk management

In order to answer the first research question: 'What are the main topics and debates in the literature on PPRM?', four main categories (topics) were derived from the inductive analysis, providing knowledge and understanding of the relevant concepts, approaches and methods regarding PPRM, so that it is natural that the categories present some overlapping between them. The main current topics identified were 'Influence of RM on project portfolio success', 'Risk and project interdependencies', 'PPR identification and categorization', and 'PPR assessment'.

### *4.1 Influence of RM on project portfolio success*

Portfolio value cannot be measured only in monetary terms; it is also necessary that other measures and strategies to assess strategic impact be identified [19]. Table 2 summarizes the categories identified in the literature associated with RM and its relation and influence on project portfolio success.

Table 2. Categories of influence between RM and project portfolio success

| Categories | Subcategories | | References |
|---|---|---|---|
| Project portfolio impact level | Company strategic objectives and project portfolio expected results | | [19, 36, 51] |
| | PPM objectives or project portfolio success dimensions | | [9, 27] |
| Moderators or contingency factors between RM and project portfolio success | Risk management quality | Risk transparency | [8, 27] |
| | | Risk coping capacity | |
| | | RM efficiency | |
| | External turbulence and Portfolio dynamics | | [6] |
| PPRM dimensions | Role Clarity | | [8, 27, 52] |
| | Formalization | | |
| | Risk management process | | |
| | Integration of risk management | | |
| | Risk management culture | | |

A concept related to portfolio risk and portfolio success is 'portfolio health', which represents the level of the project portfolio's performance in each evaluation period [36, 53]. Project performance analysis based on project success key indicators is considered as part of project health analysis [29]. As such, a healthy portfolio achieves adequate performance in its projects and at the portfolio level. In this regard, risks and unappropriated RM decisions could impact portfolio health [47]. Finally, in project-oriented companies, the PPR analysis is equivalent to the corporate or operative risk analysis, because in this type of organization project portfolio success is directly associated with business operation success, since, in these companies the project portfolio is the central axis of operations [9, 15, 54].

### *4.2 Risk and project interdependencies*

Although integration and cooperation between projects in a portfolio can increase efficiency, this, in turn, requires greater effort in PPRM because it also generates an increase in PPR [55]. Risks that can otherwise be considered as having a low impact on an isolated project may be correlated with the occurrence of the same risk in other projects in the portfolio, as well as with the materialization of other risks in the same project or in other projects [56]. The difference between correlation and interaction was an important aspect identified in the study, since the effect on PPR is significantly different for each case [57].

Interdependencies between projects are common, either in technical aspects related to project execution, or in commercial aspects associated with business issues. Interactions or synergies between projects can bring positive or negative contributions to the expected benefit and, as a whole, to the project portfolio [57, 58]. In temporal terms, two types of relationships between projects have been defined: inter-temporal or dependencies, associated with the impacts generated from the execution of previous projects; and intra-temporal or interdependencies, related to the common aspects between projects [9, 54, 59]. The relationship between projects can also be divided into inputs for PPM and outputs for project portfolio [11, 19]. Based on the works of Heinrich et al. [59], Olsson [54], Sanchez et al. [19], Guan et al. [11], Ghasemi et al. [9] and Neumeier et al. [55], Table 3 synthetizes the type of project interdependencies.

Table 3. Categorization of project interdependencies

| | | **Inter-temporal** | **Intra-temporal** |
|---|---|---|---|
| Input | *Resources:* Sharing resources between projects | | X |
| | *Technology:* Using a specific technology in several projects | | X |
| | *Outcome:* Using the end result, knowledge or capabilities gained from other projects | X | |
| Output | *Value:* Total value of two projects being greater or less than the sum of their individual values | | X |
| | *Accomplishment:* Increase of probability of success of a project as a result of undertaking another project | X | X |

### *4.3 PPR identification and categorization*

The concept related to systematic risks and non-systematic risks, derived from the Modern Portfolio Theory, is presented as the basic conceptual factor with regard to a project portfolio's risk sources [15, 53]. Project portfolio non-systematic risk, or independent risk, corresponds to the inherent risks of each project, while systematic risk, or interdependence risk, is related to the project portfolio's exposure to environmental and market conditions, corresponding to risks that affect the portfolio globally. However, systematic risk has two permutations in the literature: on the one hand, it is exclusively associated with environmental factors [15], while, on the other hand, apart from environmental factors, it includes risks from the relationships between projects [53].

Interdependent risks can generate two impacts. On the one hand, risk integration generates PPR reduction, but, on the other hand, new risks arise from the interaction, thus generating an increase in PPR [11]. For this reason, 'systematic risks' and 'non-systematic risks' represent a dichotomist risk categorization that allows for the establishment of the level (project or portfolio) at which the portfolio can be impacted, or impact level.

Regarding risk sources in the PPM context, different risk categorization structures have been proposed [7, 9, 11–13, 16, 17, 20, 53, 60], for both generic project portfolios and for specific project portfolios, such as those in IT, construction, or new product development projects. Risk categories identified by these authors are associated to a project portfolio's level of risk source, without representing a specific relationship to the extent of impacts on the portfolio in general or only on some projects within the portfolio. Table 4 synthetizes the four risk source categories, under which more specific sub-groups of portfolio risk sources can be classified.

Table 4. PPR categories and subcategories

| Category | Subcategories |
|---|---|
| Project portfolio management level | Inadequate aggregation and distribution of information, portfolio imbalance and stakeholder management [9, 20].<br>Conflicts among managers of projects, conflicts among portfolio element managers and the company´s senior managers, conflicts between stakeholders or organizational culture adverse to change [20, 53].<br>Lack in project portfolio management capabilities [9, 20, 53]. |
| Project interactions | Resource interdependencies and lack of sufficient resources [9, 13, 20].<br>Relationship between projects where developing one of them depends on one or more outputs from another project [11, 53]. |
| External conditions | Supplier and contracts [16, 60].<br>Changes in external conditions, such as norms, competitive environment, policies, or economic conditions [12, 16, 17, 60, 61]. |
| Organizational conditions | Improper portfolio structure, structural reorganizations of company or portfolio, or changes in internal policies [16, 45, 53].<br>Fund arrival rate [12, 17, 20].<br>Changes in the basic parameters of projects and programs [16, 20, 60].<br>Project and program life cycle management processes [12, 20, 60]. |

### *4.4 PPR assessment*

In order to obtain an adequate representation of risk impact, two characteristics must be considered. The first characteristic is the consideration that risk corresponds to a multidimensional measure [19, 55]. The second is the strategy for risk factors, or uncertainty representation, in order to obtain a measure of risk as a consequence [32]. In order to represent or optimize project portfolio risk, different methods have been used. Table 5 summarizes the main methods used for this purpose.

Some approaches used to assess portfolio risk are based on historical data. However, the literature highlights that generally limited or imprecise information hinders whatever process occurs in this way [56, 63]. In order to address uncertainty from the real-world perspective, alternative approaches like Montecarlo simulation, fuzzy logic, and occurrence likelihood evaluation have been used, capturing, as they do, uncertainty as an input to decision-making models based on expert judgment [9, 67–70]. Recent studies show that the fuzzy approach has not yet been fully applied in the project selection problem [71], and it has not been implemented for risk analysis in the project portfolio execution context. Montecarlo simulation also shows a very low level of incorporation into the portfolio execution phase, while being widely implemented in project portfolio selection with risk considerations, as incorporated by Neumeier et al. [55] and Panadero et al. [29].

Expected shortfall, tail conditional expectation, standard deviation, semi-standard deviation, semi-variance, value at risk (VaR), and conditional value at risk have all been identified as project and project portfolio risk measures, of which the VaR method is most frequently used in RM [66, 72, 73]. However, it is important to consider that the conditional value at risk method "provides more information than VaR and is a commonly used risk measure in portfolio optimization models" [72, p. 1654]. In this regard, the set of projects selected for a specific strategic period may be different if the risk measure used is one or another, meaning that each risk measure may lead to a different set of projects to be selected [66].

Table 5. Main methods used for risk assessment or optimization in the project portfolio context

| Method | Description |
|---|---|
| Modern Portfolio Theory [62–66] | This model uses the trade-off between risk and returns to find the efficient frontier. It is based on the traditional Markowitz mean-variance model, but other risk measures have been implemented in order to optimize a portfolio of non-divisible projects. In this regard, this approach establishes the set of projects that minimize the PPR level according to a defined return or that maximize the project portfolio return according to an established risk level. |
| Data Envelopment Analysis [60] | DEA is a non-parametric model for measuring efficiency or the capacity to have an input and an output and even several inputs and outputs using the ratio of outputs' weighted sum to the inputs' weighted sum. In the project portfolio context, the objective function of this model tends to maximize portfolio efficiency while minimizing the risk, generating an efficient frontier. |
| Analytic Hierarchy Process [12] | The process of project portfolio selection considers the set of projects and their decision criteria and sub-criteria. A comparison between each pair of criteria is carried out in order to obtain the weight (relative importance) of each criterion and sub-criterion. In the same way, each pair of projects are compared for each criterion. In this context, criteria related to risk for the project or for the portfolio are included as part of the evaluation process. |
| Complex network theory [10] | This is based on the identification of nodes that represent interdependencies between projects, establishing a structure of how projects are connected to each other. Based on the role analysis of nodes in a portfolio as a network, the method seeks to minimize the risk level while improving the efficiency of the portfolio through cooperation between projects, for which small communities or subgroups of projects are established. |
| Bayesian networks [9, 11, 18] | Bayesian networks assess cascading effects. They allow for technical, resource, and risk interdependencies to be assessed through a transitive dependencies model. In a Bayesian network, nodes correspond to random variables and arcs specify direct causal relationships between the linked nodes. A Bayesian network has conditional probability distributions for all variables. |

## 5. Future directions for research

In answer to the second research question: 'How can future research expand the PPRM research area?', four directions for future research on PPRM were identified, which should not be regarded as an exhaustive set of future directions given that each can be expanded upon and, indeed, other future directions could be identified through different or complementary analysis. Fig. 2 summarizes these future directions and outlines each main focus, also showing the relationship between future directions and the main current topics identified in the previous section.

### *5.1 PPRM as part of organizational RM*

There is a gap between RM processes, the requirements of a project portfolio threats/opportunities management, and the strategic management of threats and opportunities [54, 74]. A RM system at the project portfolio level should generate high visibility of the state of the project portfolio for top management, and it should allow planning and execution of threats/opportunities management in an integrated and coordinated manner throughout both the project life cycle and the project portfolio life cycle [54, 75]. In this sense, the integration of PPRM into the project and program level and into the organizational level using Enterprise RM systems, and other methodologies that allow a global and dynamic vision, should be explored, both in a theoretical sense and in its practical dimension. As a complement to this, risk visualization systems - the relationship with performance variables, with decision variables and their behavior over time, need to be explored. Indeed, the proposal by Silva et al. [76] and Wang et al. [10] can be seen as an example of this.

RM skills as management and dynamic capabilities according to the dynamic and changing environment of current organizations, and according to the culture and competitive environment of each organization, can be considered as relevant topics in the decision-making process [74, 77]. However, descriptions of how to incorporate dynamic capabilities in practice are rare, for which reason empirical studies on this topic are needed [16].

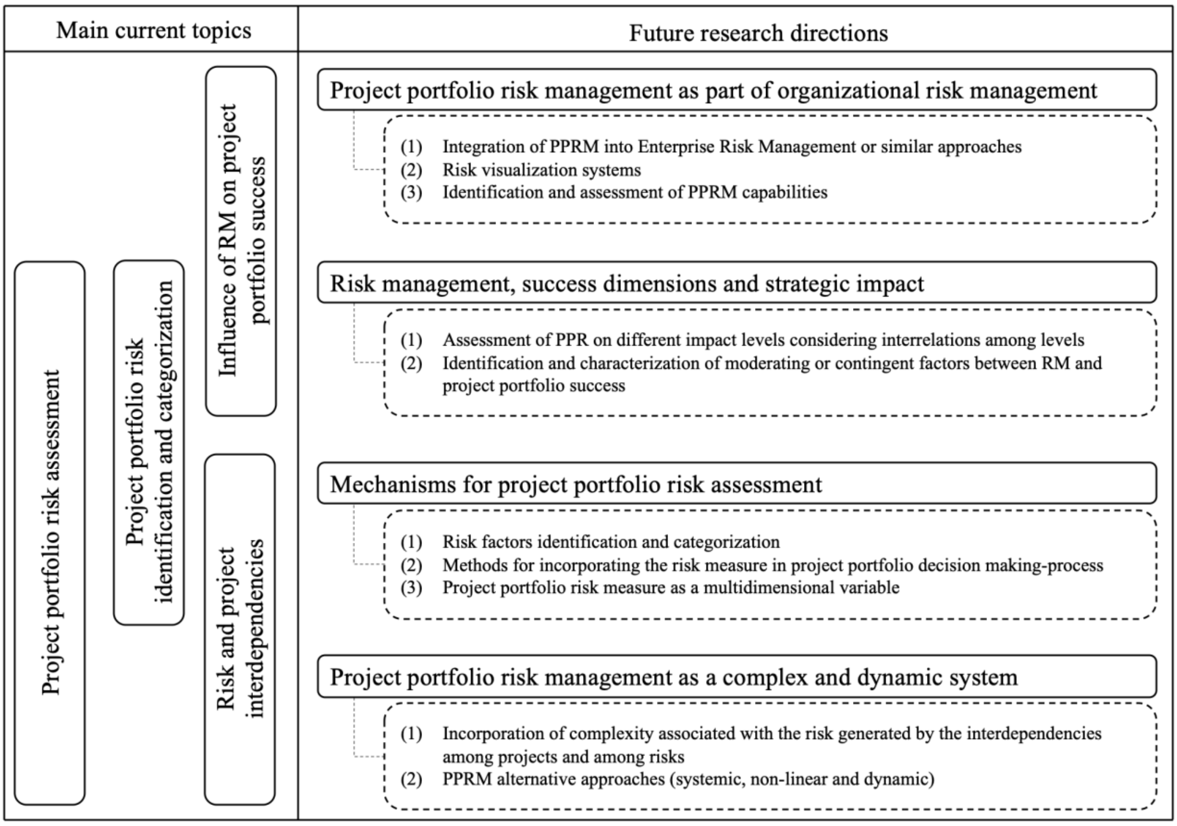


Fig. 2. PPRM main currents topics and future directions identified

### *5.2 RM, success dimensions and strategic impact*

Different levels associated with the impact of PPRM have been explored. Thus, future research could focus on establishing hierarchies between the identified levels, as well as interrelations between levels and intra-relations within each level, which, in turn, would allow the impact of the risk factors in each decision level to be established. To pursue this, empirical studies, historical information analysis and expert judgment, among other means, can be used to obtain methods, methodologies and indicators that allow for the identification and evaluation, both qualitatively and quantitatively, of the relationships between each level and the effect of the threats/opportunity factors on each of the decision levels. In this regard, conceptual frameworks have been proposed to determine the impact of the risks and opportunities on strategic and operative aspects that allow the performance of the portfolio to be monitored from a strategic perspective [8, 19, 78]. The extension of these proposals to practical applications that allow for their validation in the real context of each organization is necessary [7, 78].

From another perspective, research focused on the evaluation of RM, riskiness, or the interdependencies between projects as contingent factors between PPM and project portfolio success will allow the importance of the PPRM to be qualified and quantified, and will identify which conditions, environment characteristics or project portfolio characteristics represent aspects to be considered for adequate PPRM [52, 77, 79]. Additionally, to identify and underline the time effects, longitudinal studies would have to be employed [79], which could allow for assessment of the time effect between RM and project portfolio success. Likewise, the identification and characterization of moderating or contingent factors between RM and project portfolio success has been and should continue to be a focus of attention. Thus, empirical studies based on practice and those methodological proposals oriented to establishing the influence of different moderating factors must be developed. Identification of these factors allows for spotting RM capabilities and establishing strategies to deal with threats and opportunities [8, 19, 74].

### *5.3 Mechanism for PPR assessment*

Different categories of risk factors have been proposed in the literature. However, additional studies are required to broaden the sample size and expand upon the approaches used to obtain results that can be generalized and that determine that the categories defined are feasible in practice [9, 15, 20]. PPR categorization should be developed based on practice and expert judgment.

PPR assessment raises the need to integrate different dimensions [12, 80]. In this regard, the definition of the weight for each of the risk dimensions is a determining factor that can generate major differences in the final result. Besides this, moderating factors must be taken into account, such as the fact that the project portfolio size may have a moderating effect on the allocation of weights [15, 61]. Thus, two aspects should continue to be explored. The first is associated with the types of methods and risk measures to be implemented according to the context and information available for each project portfolio, taking into account the differences established in the literature between risk measures [63, 81].

The second aspect to be considered is associated with the use of methods that allow for the incorporation of multidimensionality. Since the incorporation of risks into project portfolios is considered a multi-criteria problem, both optimization approaches and multi-attribute approaches should continue to be explored [48, 53, 82], in the perspective of seeking to consolidate the risk inherent in a measure or a subset of measures for the project portfolio and not just in each isolated project.

### *5.4 PPRM as a complex and dynamic system*

It is generally assumed that projects are independent, with dependencies considered only when related to the sequence between projects, rarely exploring other types of dependencies [9, 55, 82]. The gaps in the literature regarding these issues, mainly associated with generic frameworks not adapted to the characteristics of the PPM environment, require that risk identification and RM go beyond this, considering the complexity associated with risks generated by the interaction between projects, risks at the project level and at strategic levels [9, 55].

Exploring alternatives to the traditional process-based approach is necessary: in the literature there are approaches to project portfolios, such as networks, knowledge networks, biological networks or complex and adaptive systems [9, 10, 55, 78], and it is necessary to deepen analysis of these alternative approaches and their application. The identification and exploration of other alternative approaches that allow a systemic, non-linear and dynamic representation, which supports the decision-making process, should also be considered [10, 55].

Approaches such as those proposed by Wang et al. [10], which look at finding the balance between project portfolio efficiency and risk through the identification of project subgroups, have great theoretical and practical importance. They make it possible to reduce not only the complexity of the decision-making process, but also to reduce the risk associated with interdependencies, generating a globally positive impact on PPR. In addition to this, approaches based on the concept of learning from information in projects and portfolios that have already been executed, such as artificial neural networks, can also help to understand the relationship between variables that make up the decision-making process [83].

## 6. Conclusions

The research reported in this paper has two main contributions to make. Firstly, it identifies the main topics and debates in the literature on PPRM. In this regard, this study has shown that PPRM has its theoretical and practical bases in the modern theory of portfolios, decision theory and RM. In addition to this, risk interdependencies, project interdependencies, and relationships between RM and project portfolio success have been shown to represent fundamental topics of PPRM. Likewise, PPR identification, categorization, and assessment were also identified as relevant to PPRM. The literature outlines some proposals oriented to defining methods, methodologies or approaches in order to support these topics. Secondly, it focuses on identifying future research directions, four of which are identified:

(1) PPRM as part of organizational RM; (2) RM, success factors and strategic impact; (3) Mechanisms for PPR assessment, and (4) PPRM as a complex and dynamic system. Therefore, the present study contributes to the current PPRM research by outlining the main topics and considering key characteristics and attributes for this field, as well as by identifying future directions, which give an informed overview for addressing PPRM challenges as a research area.

The present research process included works developed specifically in the PPRM field, as well as a structured search of those works analyzed. Conventional CA allowed for an understanding of each publication and made it possible to have a global and systemic insight into the current developments in PPRM. Between 2008 and 2014, a substantial part of the works focused on demonstrating the importance of the area, as well as exploring conceptual proposals. In recent years have specific proposals been published which identify, categorize and assess PPR, where the publications by Hofman et al. [35], Ghasemi et al. [9], and Wang et al. [10] can be seen as an example of this.

The structured literature review process carried out followed steps which are well-recognized in the literature, and which are specifically described in Svejvig and Andersen [41]. However, the step associated with the "conceptualization of topic" incorporated an unstructured and explorative search leading to the scope's definition. A set of string searches was defined and evaluated in order to obtain a string search that adequately represented the defined scope of the literature review. The above also allowed for the process of searching, evaluating, and selecting literature to be based on specific issues related to the topic under study, and not only on the authors' previous knowledge of the topic. In this regard, the incorporation of an unstructured and explorative search also brings a methodological contribution by this research towards the "conceptualization of topic" step within structured literature review processes.

Some limitations can be attributed to the findings presented. Although a structured search and analysis process was developed, Laursen and Svejvig [39] and Xia et al. [84] suggest that literature reviews can never be exhaustive and, therefore, in this process some articles or groups of articles may have been left out of the analysis. Possible exclusions may be the result of several factors: the keywords used, the search equation structure, the search scope or methodological deficiencies that could potentially be identified by other researchers. Overcoming these issues could be seen as opportunities for future work or for extensions of the research presented here. Besides this, in the literature analysis process related to qualitative analysis and CA, the cognitive bias cannot be fully eliminated, thus, the results obtained provide suggestions, but do not limit present and future directions for the PPRM research field [84].

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*Indicates that the study is part of the structured literature review.

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