Vol. 8 | No. 2 | 2020

SciKA

International Journal of Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X

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Information Systems and Project Management
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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 second number of the eighth volume of IJISPM. In this issue readers will find important contributions on IT project complexity, IT projects success factors, digitalization, and data mining for fraud control.

The first article, "Definitions, characteristics and measures of IT project complexity - a systematic literature review", is authored by Stefan Morcov, Liliane Pintelon, and Rob Kusters. As the world of Information Technology (IT) engineering becomes more complex every day, the formal study of project complexity also becomes increasingly important for managing projects effectively. As authors state, complexity is not yet clearly understood nor sufficiently defined and the terminology itself is being overloaded and over-used. This paper is a systematic literature review that aims to identify and classify proposed definitions and measures of IT project complexity. The results include a map of the identified approaches and definitions, a list of classifications of project complexity, a set of proposed measurement tools and complexity measures available to practitioners. The paper contributes to establishing a common language when discussing complexity, as well as to a better understanding of project complexity and its implications to practical IT engineering projects.

The title of the second article is "The impact of family-external business succession on digitalization: exploring management buy-ins", and it is authored by Alexander Pöschl and Jörg Freiling. Digitalization in small- and medium-sized (SME) family firms and processes of family-external business succession within these firms, are under-researched areas. As SME and their future viability are important for many economies around the world, the authors aim to study the effects of succession processes on those companies' digitalization activities. Utilizing a data set resulting from a multiple case study involving four family firms in the DACH region of Europe, the authors have performed an exploratory research. The findings indicate that incumbent and new owner-managers focus on efficiency-related digitalization activities during succession processes. More long-term issues such as changes to business models or the exploitation of external opportunities through digitalization are underrated and postponed.

The third article, authored by Carmen Iriarte and Sussy Bayona, is entitled "IT projects success factors: a literature review". IT projects are enablers of organizational transformation and business growth. Despite the contribution of methodologies and frameworks for project management, the ratio of failed IT projects remains high; then, studying critical success factors of IT projects persist as an essential issue for researches and practitioners. This paper presents a systematic literature review focused on compiling and synthesizing project success factors in IT projects. The literature search was conducted using primary journal articles. All studies agree on the relevance of studying the critical success factors in IT projects given their particular characteristics. The results indicate there is still no clear definition of project success concept. Also, there is a vast and overlapped list of factors; so, this research proposes a structure that synthesizes the most referenced factors. Findings reinforce the relevance of soft skills in IT project teams.

"Data mining approach to internal fraud in a project-based organization" is the fourth article and is authored by Mirjana Pejić Bach, Ksenija Dumičić, Berislav Žmuk, Tamara Ćurlin, and Jovana Zoroja. According to authors data mining is an efficient technology for uncovering and extracting information from large databases, widely used in different areas, e.g., customer relation management, financial fraud detection, healthcare management, and manufacturing. Data mining has been successfully used in various fraud detection and prevention areas, such as credit card fraud, taxation fraud, and fund transfer fraud. However, there is insufficient research about the usage of data mining for fraud related to internal

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control. In order to increase awareness of data mining usefulness in internal control, the authors have developed a case study in a project-based organization. It is analysed a dataset about working-hour claims for projects, using two data mining techniques: chi-square automatic interaction detection (CHAID) decision tree and link analysis, in order to describe characteristics of fraudulent working-hour claims and to develop a model for automatic detection of potentially fraudulent ones. Results indicate that the following characteristics of the suspected working-hours claim were the most significant: sector of the customer, origin and level of expertise of the consultant, and cost of the consulting services. The research contributes to the area of internal control supported by data mining, with the goal to prevent fraudulent working-hour claims in project-based organizations.

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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Definitions, characteristics and measures of IT project complexity - a systematic literature review

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S. Morcov, L. Pintelon, R. Kusters, "Definitions, characteristics and measures of IT project complexity – a systematic literature review", *International Journal of Information Systems and Project Management*, vol. 8, no. 2, pp. 5-21, 2020.

International Journal of
Information Systems and Project Management
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Definitions, characteristics and measures of IT project complexity - a systematic literature review

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Abstract:
As the world of Information Technology (IT) engineering becomes more complex every day, the formal study of project complexity becomes more and more important for managing projects effectively, to avoid poor performance and failure. Complexity is not yet clearly understood nor sufficiently defined and the terminology itself is being overloaded and over-used. This paper is a systematic literature review that attempts to identify and classify proposed definitions and measures of IT project complexity. The results include a map of the identified approaches and definitions, a list of classifications of project complexity, a set of proposed measurement tools and complexity measures available to practitioners. The paper contributes to establishing a common language when discussing complexity, as well as to a better understanding of project complexity and its implications to practical IT engineering projects.

Keywords:
project management; information technology; complex projects; uncertainty; structural complexity.

DOI: 10.12821/ijispm080201

Manuscript received: 6 August 2019
Manuscript accepted: 15 April 2020

1. Introduction

Project Management as well as Information Technology (IT) and Software Engineering are critical disciplines in today's world, well established and recognized by practitioners, with clear standards, methods, tools, certifications and professional bodies. At the same time, complex projects are still poorly understood and face significant challenges and risks. Due to the complexity of today's products, single projects, single departments or even single engineering companies can no longer develop a complete product alone, thus the industry moves towards specialized lifecycles that involve concurrent, distributed, incremental/iterative, agile development [1] [2]. IT engineering projects face significant problems related to the complexity of both the products being developed as well as to the ambiguity and uncertainty related to the methods, tools and technologies employed during the development process. IT projects are recognized by both practitioners and researchers to have a significant risk of failure [3]. One in six IT projects is expected to be a black swan, with a cost overrun of 200% on average [4]. A significant number of projects in the IT industry are reporting incredible losses: Levi Strauss' SAP implementation was a $5 million project that led to an almost $200 million loss; the "Toll Collect" project cost Germany $10 billion in lost revenue; the overall losses incurred by underperforming IT projects in the US is estimated at $55 billion annually. When the European Commission finally launched the Schengen Information System (SIS II) in 2013, the project was more than 6 years late and 8 times more expensive than the initial estimate, at a final cost of €500 million [5]. Berlin Brandenburg Airport in Germany, scheduled to open in 2011 for 2.5 billion Eur, was delayed until at least 2020 or 2021, with a final bill estimated at 6.6 billion euro [6].

Complexity in IT project management is a relatively new research area, but it draws from theoretical research such as systems, complexity or chaos theories, as well as technical research areas such as system engineering – a domain which experiences similar challenges [7]. The concept of complexity is ancient and traces its roots to Greek philosophy. Thus, Aristotle gave humanity what was probably the first definition of complexity, when arguing that *the whole is something else than the sum of its parts*; a definition simplified by Euclid as the whole being *more* than the sum of its parts [8] [9]. Complexity re-entered mainstream science and research with the theories of holism and gestalt psychology [10] [11]. Complexity is now recognized as critical to a multitude of domains such as mathematics, chaos theory, information and computing science, engineering, biology, ecology, sociology, psychology, education, economics and management.

The approach prevalent in the project management research and community of practice is that complexity affects negatively both project performance and project management performance [12] [13]. Lack of understanding and recognition of system complexity is a critical cause of poor performance of large-scale IT projects [14]. The connection between project performance, project management performance and project complexity is well established [15] [16] [17]. Large-scale, complex projects are expensive. They have a higher risk of not accomplishing objectives and a higher monetary value associated with these risks, hence significant costs are incurred when they fail. They face significant, unpredictable change, similar to Lorenz's "butterfly effect" and Taleb's Black Swan events, and are difficult or impossible to forecast [18] [19].

Therefore, the management of complex IT projects is an expensive activity, requiring special tools, expertise and skills, different from the traditional project management deterministic approaches [20] [21] [22] [23]. The skills and competences of the project manager, already key to the overall project success, become even more important [24]. The identification of complex projects is specifically important to multi-project engineering environments [25]. The traditional project management frameworks do not differentiate between the tools and methods that should be used for complex non-deterministic projects as opposed to simple and deterministic projects. The analysis of complexity allows for categorizing and managing projects more efficiently, by choosing the right framework, tools, techniques and methodologies deployed.

Thus, complexity in project management has become during the past 25 years a topic of major interest [26] [27] [28] [29] [30] [31] [32]. It is extensively described and defined, in various models, in terms of characteristics, causes and effects, a few attempts having been also made at measuring it. At the same time, the words and concepts used are ambiguous, often imported from incompletely developed sciences; they overlap, are synonyms or express different aspects of the same concept. There is no widely accepted definition of complexity itself; it can be understood differently

not only in different fields, but also within the same field; it is not yet defined why it should be measured or how [33] [34] [35]. The terminology itself is not clear - the word "complex" itself is overloaded and over-used.

This paper builds knowledge in understanding complex IT projects and in unifying the language of the domain. It also maps and compares the various approaches proposed by research. The main method employed is a systematic review of the existing literature, followed by a classification of results. The research also consolidates the results of other reviews [32] [36] [37] [38] [39].

The paper presents the research method employed, including sources, results, discussions and conclusions, and potential directions for future research. The results include a structured map of the definitions and approaches to project complexity, with characteristics, definitions, sources, causes, manifestations of complexity in project management, based on their appearance in the literature; as well as the list of classifications of complexity; a list of complexity measurement tools; and a set of measures for IT project complexity.

2. Research method

A rigorous method of identifying, evaluating and interpreting previous research related to complex IT projects was employed. Systematic reviews are relevant methods to validate theoretical hypotheses, to support the creation of a new hypothesis, defining a framework of existing research, including gaps in existing research, in order to position and suggest future research [40]. A systematic review was performed, consisting of two distinct phases: a structured search and a classification of the results.

The search was done on a large database of blind refereed research papers, which includes ScienceDirect, Scopus, Web of Science. No time filter was used. The topic appears in 1993 [41] and is formalized in 1996 [27]. The initial search strategy aimed at narrowing the searched literature to the niche topic of "complex project management". Each of the two domains "project management" and "complexity" is too broad for the scope of the current research, while their strict intersection is extremely narrow and risks excluding relevant results. Therefore, the main search phrase used was '(complex OR complexity) AND ("project management")', which returns 68,784 peer-reviewed articles for a full-text search. In order to limit the results to a manageable number, while not losing relevant articles by excessive filtering, the search phrase was only applied to the title and abstract of peer-reviewed articles, thus reducing the list to 691 articles. These results were thereafter extensively extended by snowballing – analyzing the reference lists of existing papers and backward-searching on papers who reference existing papers. All papers that matched the topic were retained, including primary and secondary studies: meta-analyses of the topic, descriptions of the industry situation, specific case-studies and structured reviews. Articles that do not match the topic were not retained. The most common cause of topic-mismatch is due to the word "complex" itself being overloaded and over-used, often to mean "large" or "difficult". The research retained only articles related to project management, while acknowledging the significant results from related domains, including complexity area itself, which provided the classic definition of a complex system: "made up of a large number of parts that interact in a non-simple way" [42]. 116 papers were found to match exactly the topic of this review, proposing definitions, approaches and/or measures of project complexity.

The articles were reviewed and summarized in free text form. The amount of information is very large, highly redundant, has heavy cross-referencing, and the approaches are at times contradictory. The second major phase of the research consisted therefore in structuring the information.

The first information structuring targeted **definitions of project complexity**. A map was created with all definitions, characteristics, sources, causes and manifestations of project complexity, as these appear in the literature. The method used was a formal method of classification. First, we removed double entries: the characteristics were grouped by lexical synonymy, each item being analyzed and either added to an existing category, or a distinct category would be created. Second, these characteristics were grouped by logical synonymy – using abstraction to logically group definitions that describe the same concept or characteristic. Depending on the specific author and approach, aspects of complexity are sometimes considered as definition, sometimes description, cause or effect. Duplicate items were maintained when the authors express different concepts with the same word. The result is a structured table of 27

characteristics, that maps the definitions and approaches, which allows for comparison between various authors (Table 3).

The second information structuring concerned **measurement criteria** and tools (Table 4). The initial inventory enumerated all the measures, criteria, characteristics, factors and indicators proposed for measuring, identifying or categorizing complex (IT) projects. Standard software measurement methodologies specifically include IT/software complexity, therefore all the items related to complexity from 2 major software estimation models were added to this list: 14 General System Characteristics defined by the Function Points Analysis methodology, which are used to compute the Value Adjustment Factor [43] [44] and 15 Cost Driver Attributes defined in COCOMO [45] [46]. This large inventory has 117 items. It includes factors even if specifically excluded from other models, such as size. A large number of items were redundant, and some not relevant. At the same time, compiling a complete inventory of all possible items insured reliability and repeatability of the process, as well as construct validity and internal validity – in order to avoid anecdotic evidence and subjective criteria [47]. In order to arrive at a simple set of usable complexity measures, each item in this initial inventory of measures was further classified using an ordinal scale with 5 ranks, according to the following criteria:

- redundancy (duplication);
- relevance;
- measurability;
- repeatability within an organization;
- repeatability across different organizations;
- predictor of high risk (probability);
- predictor of high cost related to the risk (impact).

The resulted filtered set of measures includes 28 items that are unique, relevant and measurable, i.e. all items that score at least 3 on the first 3 criteria (Table 5).

The redundancy and relevance criteria simplify the list. The measurability and repeatability criteria maintain the focus on practical issues, eliminating subjective or abstract items, thus ensuring the external validity of the results. The criteria Predictor of high-risk and of high-cost express the main motivation for the study of complexity in project management: complexity generates risk. In choosing the criteria used for this classification, certain choices had to be done which may be considered subjective. The classification is relevant for the scope of our research, it is valid and results from a repeatable process. The list is simple enough to be usable, studied and understood. Its items are practical, allow for comparison and measurability and are objective – they do not have multiple interpretations based on context or expert. The result is falsifiable, which ensures its internal validity.

The research did not attempt to assign individual weights to each item in the list, nor compute a quantitative complexity factor. There is significant empirical proof that there are major differences between complexity measures across different industry sectors, therefore the research scope and applicability was limited to IT [48]. Criteria and numeric weights are different across domains, and even between authors, experts or studies within the same field [49]. This suggests that the values of the weights vary across different types of projects, organizational and technological environments. For an assessment tool to be usable, its results must be comparable and repeatable, thus the compared projects should be reasonably similar, in terms of products, processes (technologies, methodologies and tools) and organization (environment, industry, stakeholders, users, size). This conclusion is aligned with the analysis of the effectiveness of formal methods for estimating software projects (COCOMO, FPA, IFPUG). All software estimation methods require heavy calibration using historical data related to the exact specific industry, organization, tool and technology employed for the particular projects measured. Because IT projects are particularly varied and complex [2], such estimation techniques have systematically proven to be unreliable [50]. Software estimation errors of 10% are acceptable, organizations are only concerned by errors above 100% [51]. Therefore, organizations mostly revert to expert judgment for estimation [52]. The assignation of weights to complexity measures at this time would not meet reasonable reliability and repeatability criteria, and also would not fulfill sufficient external validity conditions for the scope of this research.

3. Results

The results are:

- A chronological summary of the definitions and approaches (Table 1);
- A list of classifications and sources of complexity (Table 2);
- A structured map of the characteristics (fragment in Table 3);
- A list of complexity measurement tools (Table 4);
- A simplified set of measures (Table 5).

Table 1. Summary of definitions and historical approaches to project complexity

Author	Approach	Definition/model
[27]	First systematic approach, introducing structural complexity.	Consisting of many varied interrelated parts. Operationalized in terms of differentiation and interdependency. Categorized (mainly) as organizational and technological.
[53] [54] [55] [56] [57] [58] [59] [36]	Complexity of system development. Structural complexity. Uncertainty of goals and methods. Multiplicity and ambiguity.	Dynamic complexity, in addition to detailed (structural) complexity. Ambiguity or uncertainty as sources. Categorized as "task-related" (business, external, organizational) or "system-related" (technological). Multiplicity, i.e. many approaches and end-states. Ambiguity, i.e. conflict and uncertainty in decisions.
[37] [60] [61]	Complexity in social sciences or biology. Complex systems theory.	Complex society is characterized by open systems, chaos, self-organization and interdependence. Emergence, unpredictability.
[62] [63] [25]	Holistic models, delineating definition, sources, manifestations, characteristics of project complexity.	"Difficult to understand, foresee and keep under control". Ambiguity, uncertainty, propagation and chaos are considered not as sources, but consequences of complexity.
[32]		Five dimensions of complexity: structural, uncertainty, dynamics, pace and socio-political.
[64]		Two dimensions of project complexity (detail and dynamic complexity) and three dimensions of project emergent properties (absorptive, adaptive, and restorative capacities).

Table 2. Classifications of project complexity

#	Classification and source
1.	Technical vs. organizational complexity [27] [54] Also: task-related complexity (business, external, organizational complexity) vs. system-related (technological complexity) [53] Also as: the TOE model - technological, organizational, environmental [65]
2.	Structural vs. dynamic complexity [66] [59] Or: detail vs. dynamic [36] [64] Variation: structural complexity vs. uncertainty [54]
3.	Simple, complicated, complex, really complex projects [36] [39]
4.	Objective (descriptive) vs. subjective (perceived) complexity [67] [68] [69] [70]
5.	Uncertainty in goals vs. uncertainty in methods [41]
6.	Multiplicity (many approaches and end-states) vs. ambiguity (conflict and uncertainty in decisions) [57] [58]

#	Classification and source
7.	Ambiguity (unknown) vs. complexity (unpredictable) [55]
8.	Size, variety, interdependencies, context-dependencies [63] [71]
9.	Ambiguity, uncertainty, propagation and chaos [63]
10.	Size, innovation, interdependencies, variety [56]
11.	Variety vs. variability vs. integration [72]
12.	Uncertainty of faith (uncertainty, uniqueness, unknown), of fact (strong interdependencies), of interaction (politics, ambiguity, multiculturalism) [73] [74]
13.	Structural, technical, directional, temporal [75]
14.	Structural, uncertainty, dynamics, pace and socio-political [32]
15.	Project emergent properties: absorptive, adaptive, and restorative capacities [64]

In addition to Table 2, some variations of classifications were also proposed [12] [21] [76] [77] [78] [79] [80].

Table 3. Structured map of the characteristics of complex projects

Characteristics	Author:	**(Baccarini, 1996)** [27]	**(Williams, 1999)** [54]	**(Vaaland & Hakansson, 2003)** [56]	**(Bertelsen, 2004)** [60]	**(Xia & Lee, 2005)** [66]	**(College of Complex Project Managers And Defence Materiel** [81]	**(Cooke-Davies, Cicmil, Crawford, & Richardson, 2007)** [61]	**(Mulenburg, 2008)** [82]	**(Whitty & Maylor, 2009)** [59]	**(Vidal, 2009)** [63]	**(Hertogh & Westerveld, 2010)** [36]
1.	Multiplicity					SC						
2.	Ambiguity					DC			x		Manif.	
3.	Uncertainty		x			DC	x		x		Manif.	
4.	Details (structural)	x	x						x	x		x
5.	Dynamics					DC			x			x
6.	Disorder						x					
7.	Instability						x				Manif.	
8.	Emergence				x		x	x		x		
9.	Non-linearity				x		x	x				
10.	Recursiveness						x					
11.	Irregularity						x					
12.	Randomness						x	x				
13.	Dynamic complexity = parts interact					SC	x		x			x

Characteristics / Author:	(Baccarini, 1996) [27]	(Williams, 1999) [54]	(Vaaland & Hakansson, 2003) [56]	(Bertelsen, 2004) [60]	(Xia & Lee, 2005) [66]	(College of Complex Project Managers And Defence Materiel [81]	(Cooke-Davies, Cicmil, Crawford, & Richardson, 2007) [61]	(Mulenburg, 2008) [82]	(Whitty & Maylor, 2009) [59]	(Vidal, 2009) [63]	(Hertogh & Westerveld, 2010) [36]
14. Uncertainty of objectives and methods		x				x					x
15. Varied stakeholders, competing views			x		SC	x					x
16. Changing objectives				x		x					
17. Adaptive, evolving				x		x	x			Manif	x
18. Involves double-loop learning						x					
19. Explanation of states of stability-instability				x			x				x
20. Size			x							Driver	
21. Variety			x		SC					Driver	
22. Interdependence			x		SC					Driver	
23. Context										Driver	
24. Innovation			x								
25. Difficult to understand										Def.	
26. Difficult to foresee				x						Def.	
27. Difficult to control										Def.	

In Table 3, SC stands for structural complexity; DC: dynamic complexity; Def.: definition; Manif.: manifestation. Various models and tools were proposed for measuring the degree of complexity, defining approaches scales, measures and criteria [66] [33] [83] [84] [85] [86] [25] [87] [67] [88] [39] [71] [89] [90] [65]. Table 4 presents the most recognized complexity measurement tools.

Table 4. Complexity measurement tools

#	Measurement tool
1.	The complexity Assessment Questionnaire proposed by the Project Management Institute [91]
2.	The Crawford-Ishikura Factor Table for Evaluating Roles (CIFTER) supported by the International Project Management Association [92]
3.	The Project Complexity Assessment and Management tool (PCAM) [93]
4.	Hass' Project Complexity Model Formula [86]
5.	Vidal's AHP (Analytic Hierarchy Process) measurement tool [25]
6.	"Acquisition Categorisation" (ACAT) of the Australian Defence - assesses levels of complexity against the attributes: cost (size), project management complexity, schedule complexity, technical difficulty, operation and support, commercial [94]
7.	Project Complexity and Risk Assessment tool (PCRA) of the Treasury Board of the Canadian Government [95]

Tables 5 presents the complexity criteria retained based on uniqueness, relevance, and measurability, classified by family [63] and source (organizational, technological) [27].

Table 5. Simplified set of measures of complex IT projects

#	Criterion	Family	Organizational	Technological
1	Staff quantity (team size)	Size	Yes	
2	Number of stakeholder organizations (subcontractors, customers, partners, investors, users…)		Yes	
3	Size of capital investment (budget), including resources		Yes	
4	Number of deliverables		Yes	Yes
5	Effort (man-days)		Yes	Yes
6	Duration of the project		Yes	Yes
7	Number of business areas involved			Yes
8	Number of function points			Yes
9	Reusability - application developed to meet one or many user's needs	Variety		Yes
10	Geographic distribution of the project team (collaborating frequently)		Yes	
11	Variety of the interests of the stakeholders		Yes	
12	Variety of information systems to be combined (number of application types)		Yes	Yes
13	Variety of skills needed		Yes	Yes
14	Variety of interdependencies			Yes
15	Competing objectives			Yes
16	Uncertainty and stability of the objectives and requirements		Yes	Yes
17	Availability of people, material and of any resources due to scarcity of supply on the market or in the organization	Interdependencies	Yes	
18	Specifications interdependence			Yes
19	Interdependence between the components of the product			Yes
20	Uncertainty of the project plan - level of detail and expected stability			Yes
21	Uncertainty and stability of the methods (clear project management methodology, clear software development methodology, risk management, communication, etc.)			Yes
22	Unknown and/or unstable legal and regulatory environment	Context	Yes	Yes
23	Cultural configuration and variety	Interdependencies /context		Yes
24	Environment organizational complexity (networked environment)		Yes	
25	Environment technological complexity (networked environment)			Yes
26	Knowledge in the organization - organizational (business and industry; e.g. new business or a new type of customer)		Yes	
27	Knowledge in the organization - technical (technology, infrastructure, external interfaces, development platform, tools...)		Yes	
28	Level of change imposed by the project on its environment		Yes	

4. Discussion

The main approaches identified for defining IT project complexity are subjective/objective, size-related, structural and dynamic. They are summarized in Figure 1. The subjective (perceived) complexity paradigm assumes that the complexity of a project system is always improperly understood through the perception of an observer, while the objective (or descriptive) complexity paradigm considers complexity as an intrinsic property of a project system [67] [68] [70].

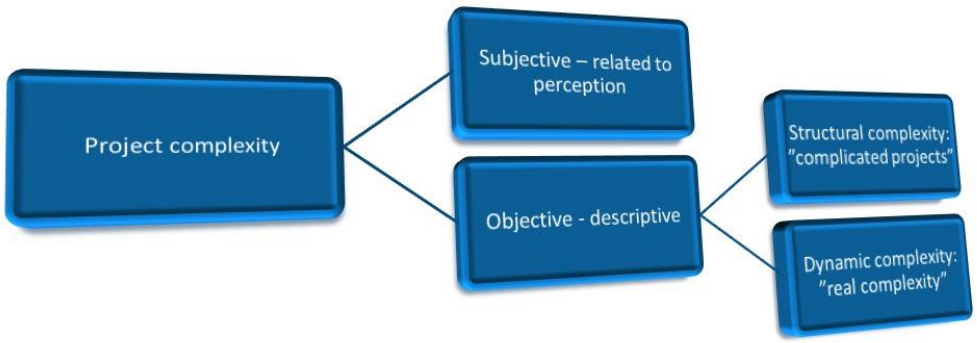

Figure 1. Project complexity paradigms

The simplest approach is based on **size**- large projects are considered more complex. Size may refer to capital, budget, effort, duration, number of stakeholders or technical components [96] [97] [59] [56]. Pure theoretical approaches to project complexity consider that size is not a valid factor, since a large project without interdependencies could theoretically be split into several small simple projects [27]. In practice, size cannot be separated from complexity; it is strongly related to uncertainty [98] and risk exposure [99] [100]. Mega-projects and complex projects have common characteristics [101]. Size is always a strong predictor of complexity. Also, due to budget constraints, only large projects should be treated as complex in practice [63] [102] [71] [67].

Structural, or descriptive, spatial, detailed complexity, is defined as consisting of many varied interrelated or interacting parts – with a strong accent on differentiation (varied) and interdependence [27] [69]. It may refer to technical (product) or organizational complexity [54]. Descriptive complexity considers complexity as an intrinsic property of a project system [68] [67]. Structural complexity allows for objective measures, thus is the most common approach.

Dynamic complexity (or **true, real complexity)**, includes uncertainty, ambiguity, variability aspects [66] [57] [58]. Uncertainty in both goals and methods is typical for complex projects [41] [28] [81] [54] [57] [58] [103]. Complexity arises from ambiguity or uncertainty related to the tasks or the system [53]. It relates to open systems, chaos, self-organization and interdependence, self-modification, upward and downward causation and unpredictability, adaptiveness [37] [60] [75]. They are defined by nonlinearity, continuous interactions with their environment and complex feedback loops [61]. They are emergent, therefore control on individual components does not guarantee the control, nor the overall behavior, of the whole project [59]. They display significant changes provoked by small factors, similar to Lorenz's "butterfly effect" [18].

Structural complexity (complicatedness) may be considered a cause and/or an effect of "real complexity" [59] [38] [39]. Approaches based on cybernetics differentiate between simple, complicated and "really complex" projects, associating structural complexity to mere complicatedness [104] [67], solvable with additional resources and decomposition / divide-et-impera techniques [7].

The described approaches are complementary. Combinations give a more comprehensive perspective [62] [63] [73] [32].

5. Conclusions and implications

IT project managers notice early in their careers that complexity is ubiquitous in their projects and products. Practitioners understand and recognize the importance of complexity, that it cannot be avoided or eliminated completely, that it is highly expensive, and sometimes complexity is useful and/or needed for the success of IT projects and products. The industry recognizes more and more the need for studying complexity in engineering projects, as it needs practical tools and methods for identifying, measuring and managing complexity. The industry is still mostly guided by expert judgment: "You will know it when you see it" [85]. There is no specific framework or methodology for the management of complex IT projects, but collections of guidelines and best practices start to appear. The identification and analysis of complexity still suffer from vague definitions, ambiguity in the terminology employed, confusion between definition, sources, causes, characteristics, manifestations and metrics. These issues affect theoretical research as well as the performance of IT industry projects

Research in project complexity is based on theoretical and empirical methods, starting from systems theory, complexity theory, natural and social sciences, chaos theory. It includes case studies and theoretical models. Limited research has been conducted on metrics and measuring IT complex projects and very little in defining methods for managing them. Most research simply stops at concluding that metrics and tools are required but not available or not reliable.

Even if IT and systems engineering face similar issues as project management regarding the management of complexity, significant success can be observed in these industries, proven by the plethora of very successful and complex products developed daily: the industrial and personal devices around us are more and more complex: smart-phones, autonomous vehicles, space shuttles, robots, intelligent home appliances, etc. [7]. The holistic approach adopted by modern systems engineering, including the concept of SoS (System of Systems), would benefit and help advance the project management body of knowledge [105] [106]. While project management practitioners focus on the negative aspects of complexity, they also acknowledge that it is often associated with innovation [12] [107]. We propose therefore to revert to a systems-thinking approach in project management; to acknowledge the relation between project complexity, product, process, and organizational complexity; to acknowledge the importance of complexity in everyday life and accept that systems, both natural and artificial, acquire complexity; and to use this for advancing IT project management. Such concepts as "positive complexity", "appropriate complexity" and "requisite complexity" [108] will be critical to advancing IT project management, and can constitute key directions for future research. Managing complexity is expensive, but ignoring complexity is even more expensive. Thus, it is even more important for practitioners to recognize, understand, measure and classify complexity and complex projects; to differentiate between different types, sources and effects of complexity. Based on cost-benefit analysis, practitioners will then be able to make informed decisions on how to manage each particular project and each aspect of complexity.

Further research is needed for developing methods and tools for the measurement and management of complex IT projects, in tight correlation and with direct impact in the industry. Research questions are also proposed by authors [109]. Potential directions of research are the analysis of the relation, similarities, and synergies between IT project complexity and complex systems engineering, risk, and vulnerability management [67], or the application of systems theory and systems thinking to IT project complexity management.

6. Limitations and main contributions

While a series of measures were taken for ensuring validity and reliability, several limitations apply. The researched literature was narrowed so that the research remains feasible, while ensuring that relevant articles are not excluded. The Science Direct database was used in the search, as it covers the largest number of journals relevant to the topic. The search phrase was applied only to the titles and the abstract of peer-reviewed articles, so as to limit the number of articles while retaining relevant research. The search was limited to articles in English. The summation of the reviewed articles was done manually, but was documented for each article, in order to ensure traceability and repeatability of the process. Also, each reviewed article was categorized and archived individually.

The literature review was not limited strictly to an industry, but it is focused on IT. The domain of applicability of the complexity measures is especially limited to IT projects, in order to increase specialization therefore usability.

The results are summarized and formatted to be accessible to a wider audience. The summary tables and the Results section indicate the referenced articles.

All models are of course simplifications of reality. They cannot describe reality in all its aspects, but they help us analyze and discuss the topic using a common language and a standardized approach. Important about models is that they should be practical, rather than "correct". This paper allows the formation of a common language for IT project management practitioners, aligned with mainstream project management terminology and methodologies.

IT project complexity is a challenging and complex issue itself, which requires special consideration for building new knowledge and value for practitioners and industry. This paper constitutes a building block in the study of and research into IT engineering project complexity.

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

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A. Pöschl, J. Freiling, "The impact of family-external business succession on digitalization: exploring management buy-ins", *International Journal of Information Systems and Project Management*, vol. 8, no. 2, pp. 24-46, 2020.

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Abstract:
Digitalization in small- and medium-sized (SME) family firms and processes of family-external business succession within these firms are under-researched areas. As SME and their future viability are important for many economies around the world, we aim to study the effects of succession processes on those companies' digitalization activities. Utilizing a unique data set comprising of around 340 pages of transcribed interviews within a multiple case study involving four family firms in the DACH region of Europe, we perform exploratory research of this matter. Our findings indicate that incumbent and new owner-managers focus on efficiency-related digitalization activities during succession processes. More long-term issues such as changes to business models or the exploitation of external opportunities through digitalization are underrated and postponed. Our findings contribute to both digitalization and family firm literature and we provide suggestions for future research in this regard.

Keywords:
family business succession; digitalization; digital transformation; entrepreneurship theory; management buy-in.

DOI: 10.12821/ijispm080202

Manuscript received: 18 September 2019
Manuscript accepted: 17 May 2020

1. Introduction

Family firms are encountering two rising waves that will dramatically shape their way of doing business. One wave relates to the digital transformation of businesses in general [1] and to family businesses in particular [2]. The other one is even more specific to family companies: business succession [3]. Business succession is among the most relevant and critical issues family firms have to face at some point in their life [4], [5], [6]. Family firms' idiosyncrasies [7], [8] make the succession process a challenge for corporate performance and survival [9], [10]. This is even more the case when looking at family-external succession which is a peculiar succession mechanism that has received little attention in existing family business research [11], [12], [13], [14]. Such family-external successions have been found to come along with serious ramifications for the businesses concerned [9], [15] which is not surprising as such succession typically follows a complex, multi-staged and dynamic process [16], [17], [18]. Unfortunately, especially the process of family-external business succession, the 'exit gate' of family business research, is under-researched [19], [20]. This is in stark contrast to the relatively good progress that has been made on primarily family-internal succession processes [21], [22], [23]. Typically, studying family firms is a challenging task as such businesses have been described as "difficult to access for research purposes" [16, p. 79] and rather secretive in nature [17].

The topic has enormous practical relevance. While 25 percent of all business successions in Austria were family-external ones in 1996, the latest figures of 2006 indicate a jump to 50 percent [18]. During the same period family-external successions in Switzerland climbed from a share of 39 percent to close to 50 percent [19]. In Germany roughly 40 percent of all business successions between 2002 and 2008 involved family-external successors [20]. Despite an absence of more recent figures, it is reasonable to assume that external business succession continues to be of high relevance. In Bavaria, one of Germany's economically most active federal states, roughly 40 percent of current owner-managers aim to find family-external successors due to a lack of internal ones in the next two to ten years [21]. Again, there is a lack of research as to external business succession [22], [12] and this lack has practical implications insofar as research has failed to provide perspectives and implications for external successors [23]. Given that 500,000 small- and medium-sized entities (SME) will need to find successors by 2022 [24], the economic relevance is evident. Moreover, it is also of considerable political and societal importance as between 61% and 70% of the Swiss, German and Austrian workforce are employed by family firms [25], [26], [27].

In addition to this wave of business succession across many small- and medium-sized family firms there is an "unprecedented wave of digital transformation" [1, p. 301] currently hitting the shores of these businesses. Various terms such as digitization, digitalization or digital transformation refer to more or less substantial changes of doing business [28], [29], [30], [31]. Benefits of digitalization are manifold and include cost savings, more efficient processes or closer ties to customers [30], [31], [32]. Still, those benefits do not come automatically, and digitalization can represent a major challenge for companies [33], [1]. Specifically, most family firms are small- and medium-sized [34] and such businesses face particular issues related to digitalization. They tend to lack resources [35], [36] and expertise needed for such digitalization [37], [quinton] and are often very much dependent on the digital skills of owner-managers and their attitudes towards changes [37], [38], [2]. Moreover, scholars and family firm practitioners have only been starting to explore digitalization within the context of family firms and are still in the process of exploring and gaining experience [39]. In this regard, there is a specific lack of understanding of digitalization issues in small- and medium-sized companies [40].

When combining these two very current issues of family-external business succession and digitalization our main research question arises:

RQ: How is digitalization being considered by owner-managers during a family-external succession process in small- and medium-sized firms?

The purpose of this paper is to explore this question by making use of a unique data set comprising of a multiple case study of four family firms in the DACH region. 340 pages of transcribed in-depth interviews have been collected on an entirety of fifteen interviews held with various stakeholders, including previous and new owner-managers. Given the above-mentioned difficult research access to family firms and the under-researched natures of both the family-external

business succession and digitalization in small- and medium-sized family firms, the present study contributes to existing research in two main ways: first and from a methodological point of view, it generates exploratory and quasi-longitudinal insights into the process of family-external business succession and its effects on these firms' various layers of digitalization during that time. Secondly, we employ entrepreneurship theory in order to conceptualize pre- and post-succession phases within the external succession process in order to make it more susceptible for both data collection and exploration of its dynamic character.

The remainder of this paper is structured as follows: in the next chapter we conduct a literature review on the many facets of digitalization and family-external business succession and discuss their interplays and relevance for small- and medium-sized family businesses. Afterwards, we conceptualize the succession process' division in two main phases and its effects on digitalization by creating three research propositions. In the subsequent section we explain and argue our methodology by detailing the case study approach employed to research on the formulated propositions. Consequently, we present our findings and interpretations and conclude with discussing those results as well as naming implications and limitations as well as promising areas for future research.

2. Literature review

2.1 Family firms and business succession

There is a vast number of categories which family firms can be placed in, starting from dimensions such as the families' concentration of ownership to their size in terms of sales and employees or the degree of family involvement in the companies' leadership team [41], [42]. Various authors point out that firm size is a relevant factor when studying such family firms as organizational or resource-related differences between small and large ones can be substantial [42], [43]. Indeed, while there is data-backed agreement that most family firms are small- and medium-sized [44], [38], [37] there is no universally accepted definition of small- or medium-sized. The definition given by the European Commission [45] has been described as the "only semi-official" [46, p. 21] one. According to this definition, SME are those firms that employ between 10 and 249 employees and that either have an annual balance sheet volume of between 2 and 43 Mio. € or an annual turnover of between 2 and 49 Mio. € [45]. Stemming from its practical significance and widespread adoption [46] our study utilizes this SME definition.

With turnover or balance sheet and employment dimensions already narrowing down the manifold options of defining family firms, the actual family-related characteristics of such firms still hang in the balance. As Werner [41] and Haunschild et al. [47] point out, the unity of ownership and management is a defining feature of family firms and that at least 50 percent of voting shares need to be held by family members for a firm to classify as a family business. As Haunschild and Wolter [48] add, those voting shares can be held by sole owners or even a group of owners and the classification holds in the case of some external managers sitting on the management board next to family members. This feature is especially relevant in the context of the present study as a particular way of family-external business succession has been studied, namely management buy-ins (MBI). These involve external persons (managers) that purchase the majority, or, in larger deals, a significant percentage of a firm's voting shares [49]. In that these managers also take up management positions in the firms whose voting shares they at least partly acquired they possess decisive rights in steering the firms and consequently become the new owner-managers [49]. We therefore define small- and medium-sized family businesses (SMFB) in the dependence on the European Commission [34] and Haunschild and Wolter [48] as follows:

Small- and medium-sized family businesses (SMFB) are those firms that employ between 10 and 249 employees and either have an annual turnover of between 2 and 49 Mio. € or an annual balance sheet volume of between 2 and 43 Mio. € and whose sole owners or group of owners have decisive rights of the particular firms' voting capital and whose sole owners or group of owners belong to the management board either on their own or in combination with external managers.

Family firms in general have been associated with some sort of 'familiness' [50] as a bundle of specific resources stemming from family involvement and intra-family relationships [51], [52], [53] as well as various unique features such as patient, i.e. owners' long-term invested capital [54]. Furthermore, especially the role, attitudes and skills of owner-managers in SMFB have been found as important influencing factors for the organization and the conduct of those firms [55]. As many SMFB are limited in their funding options due do their size [56] these businesses rely to a large extent on owner-managers' willingness to put funds into the business [55]. This financial dependence in turn increases owner-managers' central role in shaping and controlling the firm [9], [55], for instance ranging from their being the main point of contact for suppliers or banks [56] to their central role in defining the criteria for business success. Such centralized decision-making is typical for small- and medium-sized firms in Germany and Austria [57]. While such an organizational setup allows quick decision-making as mainly the owner-manager is involved [58] it is precisely this personalized way of doing business that has the potential of complicating the process of family-external business succession [59], [60].

In light of this personalized way of doing business in many SMFB, the relevance and challenges of MBI are not to be underestimated. MBI are a relatively recent phenomenon in the world of business succession [61], yet their share out of all (family-external and internal) business successions in Germany alone has been estimated to be 16.5 percent between 2005 and 2009 [62]. In absolute numbers this estimate would yield a total of 3,630 MBI per year in Germany in this period [15], [30]. Now, MBI concern the transfer of the above-mentioned decisive rights from a firm's sole owner or its group of owners to outside managers [63]. Especially for SMFB such MBI are a fitting succession mechanism as the personalized way of doing business often continues with a new owner-manager [64]. Those outside managers often receive financial support by capital providers who in turn get to hold some percentage of the acquired firm's voting shares [65], [66], [67]. In order to classify as a genuine management buy-in, Görres and Moss [66] as well as Wright et al. [49] argue that these shares of capital providers need to be limited and external managers should at least hold 25 percent of the acquired firms' voting shares. In line of this reasoning we define management buy-ins as "*the transfer of ownership whereby executive control of a business is gained by a manager or entrepreneurs or a team of managers who were not working for the company before the transaction*" [61, p. 5, emphasis added] *and who acquired and hold at least 25 percent of the firm's equity, possibly in combination with providers of financial capital who hold the majority of the remaining shares* [66], [49].

2.2 Digitalization

Among the many terms associated with the use of new and digital technologies 'digitalization', 'digitation', 'digitization' or 'digital transformation' have been the most widely used [68], [69], [41]. Authors tend to agree that digitalization and digital transformation can be used interchangeably and refer to more or less the same meaning, namely fundamental changes within business, society or politics that are driven by digital technology [51], [29]. As to the business context, such changes concern nearly all areas of firms ranging from individual processes to the organizational setup and whole business models [31], [1], [40]. Digitalization in turn stands for the alteration and change of processes, organizations or business models in a way that might completely change their function, significance or shape or even lead to completely new products [70], [71], [72].

Following the above discussion, in this study we employ the definition of digitalization given by Parviainen et al. [29] which states that digitalization "*is defined as changes in ways of working, roles, and business offering caused by adoption of digital technologies in an organization, or in the operation environment of the organization*" (p. 64). According to Parviainen et al. [29] such changes typically relate to areas of internal efficiency (such as processes and reporting systems), external opportunities (such as related to customers and products) and business models (such as new ventures).

The benefits of such digitalization include increased innovation [39], [73], [1] and gains in productivity [74]. In general, Buhl and Kaiser [75] classify and Neumeier et al. [76] substantiate the benefits of digitalization according to a total of five layers, namely related to customers (e.g. product innovation), business models (e.g. new business ventures), business processes (e.g. increased productivity), applications and systems (e.g. enhanced analytic tools) and infrastructure (e.g. modernized technical equipment). Especially in SMFB, however, digitalization is a dramatic

challenge owing to these firms' often limited technical capabilities and widespread hierarchical organizational structure [2], [33], [36]. With regard to the latter, Elbeltagi et al. [37] find that owner-managers in small- and medium-sized firms play a central role when it comes to these firms' adoption of new technologies. This is significant as Bollweg et al. [77] find that owner-managers tend to either underestimate customer expectations of digital services offered or tend to implement such digital offerings only when competitive and customer pressure mount. Such behavior by owner-managers might relate to difficulties of small- and medium-sized businesses finding and retaining new talent which is of particular concern given the relatively new area of digitalization [78]. Taiminen and Karjaluoto [38] find that many small- and medium-sized businesses do not exploit the full potential of digital ways of working and question whether owner-managers have understood the signs of the time.

3. Theoretical and conceptual foundations and research propositions

As noted above, business successions play out in stages and constitute a process [17]. When studying such temporal phenomena involving a variety of stakeholders, a conceptual framework is helpful in guiding and structuring the empirical investigation [79]. Through it, we aim to create causal propositions that direct our data collection and analysis [80], [81].

The first step involves addressing the sort of theoretical lens that we employ for our investigation. Business succession can be perceived as a form of entrepreneurial behavior as successors basically start to own and manage their new firm [67]. Moreover, SMFB have been widely linked to entrepreneurship theory and research [9], [21], [67]. When dealing with incumbent and new owner-managers such a process involves a difference in knowledge about the business at hand [15]. Thus, these main stakeholders are presumed to possess asymmetric information which is likely to translate into different decisions being made [82]. The present paper therefore takes a subjectivist theoretical stance. With small- and medium-sized family firms' digitalization during family-external business succession being this study's explanandum, the exploration of why and how such businesses' digitalization efforts will be affected during such a transitional process marks the research aim of this study. This transition, however, is not straightforward to research. The process as such needs to be delimited for precise data collection and analysis [32]. We follow various contributions in that we conceptualize two main succession phases: pre-buy-in and post-buy-in [32], [83], [84], [85], [15]. The pre-buy-in phase is relatively straightforward to define as *the time period between current and new owner-managers' first contact and the contractual finalization of the management buy-in transaction* [15]. Finding a definition for the post-buy-in phase presents a more difficult endeavor. One could argue that for new owner-managers the post-buy-in phase lasts until the moment there is another change in ownership and/or management. From a research point of view such a long period of time is hardly measurable. That might well be the reason why post-succession phases in general have been found to be often neglected in research [83]. We try to circumvent this issue by employing entrepreneurship theory and especially its construct of entrepreneurial balance [86]. Such a balance is achieved when new owner-managers have become familiar with their firm's formal and informal matters such as processes and culture. This allows conceptualizing the post-buy-in phase as one that takes up considerable time for new owner-managers [86], [15]. Thus, we define the post-buy-in phase as *the time period between the finalization of a management buy-in transaction and the achievement of a new entrepreneurial balance for new owner-managers* [15].

Now, when looking at digitalization efforts of SMFB, preliminary evidence suggests a degree of centralization when bringing forward digitalization projects and this centralization follows the lines of SMFB management by owner-managers in general [77], [2], [38]. However, as owner-managers have been found to play a central role in adopting digitalization [37] we do not focus on owner-managers' past actions as to such digitalization. Rather, we look at their role during the process of business succession. In this regard Taiminen and Karjaluoto [38] point out that a lack of resources and especially time is a significant barrier to the adoption of digitalization by owner-managers and small- and medium-sized firms in general. In the pre-buy-in phase, incumbent owner-managers are supposed to facilitate the due diligence of their business. A due diligence is "a purposeful, systematic, professional investigation of business opportunity and risk during on-going sale negotiations" [87, p. 156]. Thus, owner-managers in cooperation with their tax planners or outside consultants prepare tax documents, sales forecasts, historical financial information and similar data so that parties interested in the MBI can investigate the firm and offer a purchasing price [87]. All this preparation

is complicated and time-consuming [88]. Next to many owner-managers' lack of initiative as to digitalization even in non-succession times [77], Hopkins et al. [89] reason that during a succession owner-managers tend to neglect the digital side of a due diligence, for instance by not creating a register of all digital assets in the business. Similarly, Sherer et al. [90] note that digital topics such as new technologies or electronic data demonstrate rather recent and still incomplete areas of due diligence investigations. Following this discussion, we assume the pre-buy-in phase to focus on traditional areas of due diligence such as tax, organization and financial and less so on digitalization. Thus, we formulate our first research proposition:

P1. Small- and medium-sized family businesses' incumbent and new owner-managers focus less on digitalization-related areas in the pre-buy-in phase compared to classic due diligence topics.

Within the context of succession especially post-succession phases are highly difficult for both new owner-managers and firms. Specifically referring to MBI, business failure rates in the aftermath of successions range between 8 percent and 32.5 percent [49]. Robbie and Wright [61] find that despite complicated due diligence processes in MBI, new owner-managers struggle with a lack of information of their newly acquired firms, with unanticipated issues such as a lower-than-expected quality of warehouse stocks and the maneuvering through the firm's accounting and reporting systems. Laub [91] adds the vital function of looking at cash-flows and accounts receivables and payables as priorities for new owner-managers in the immediate post-buy-in phases. New owner-managers need to build rapport with the firms' employees as soon as possible in order to facilitate trust and performance which Howorth et al. [59] found to be a challenging undertaking for new owner-managers. Adding to that, Weber [22] finds that especially in cases of external business succession, opportunistic behavior by some employees needs to be addressed by new owner-managers. This may explain why changing employees' incentive systems are a common prioritized task among new owner-managers in MBI [61]. Such changes correspond to Schmude and Leiner [60] who note that many small- and medium-sized firms require financial restructuring by their new owner-managers. In light of this discussion, we expect new owner-managers to be very much occupied by classic business administration topics in the post-buy-in phase. These topics include cash-flow management, building relationships with employees, customers and suppliers, the familiarization with accounting and reporting systems and gaining in-depth and intimate knowledge about their new companies. These assumed tasks correspond to issues related to exploitation as opposed to exploration [92]. Taking into consideration the definition of digitalization given by Parviainen et al. [29] and its relation to the digitalization aspects of internal efficiency, external opportunities and business models, we assume new owner-managers to focus on the first aspect of digitalization, if at all. Given the likely number of business- and finance-related priorities for new owner-managers, we anticipate there is less focus on the creation of new business models in the immediate aftermath of the pre-buy-in phase. Similarly, the exploration of new external opportunities is not expected to be a priority in the immediate post-buy-in phase. Thus, we propose:

P2. When new owner-managers deal with digitalization in the post-buy-in phase, they focus their time and resources on aspects related to internal efficiency and exploitation.

One component accompanying many mergers and acquisitions (M&A) transactions is a vision or long-term strategy formulated by new leaders when acquiring a company [93]. Successful business integration involves leaders that think about and formulate clear long-term strategies [94]. With regard to digitalization in SMFB, Bley et al. [95] find that a majority of 55 percent of German businesses in their study of the Dresden region overestimate their degree of digitalization and many of those firms are small- and medium-sized. Similarly, Sommer [96] reports on a lack of interest in many small- and medium-sized firms when it comes to digitalization. Still, there is preliminary evidence and reason to believe that in businesses general and SMFB in particular there is a rising awareness of the significance of digitalization [96], [97]. This ties in to business succession as a potential engine for innovation and exploration as successors enter the company with new ideas and visions [98]. Following our second proposition, we assume that in spite of more urgent business priorities in the post-buy-in phase, new owner-managers will attempt to at least study the

possibility of utilizing the more long-term and strategic elements of digitalization such as the ones related to external opportunities and business models. Thus, we propose:

P3. Already in the post-buy-in phase, new owner-managers will study the possibility of or formulate visions for the utilization of more radical and longer-term aspects of digitalization such as the ones relating to external opportunities and business models.

4. Methodology

Digitalization in SMFB demonstrates a still under-researched topic [39], [40] and a research methodology has been sought to further our understanding of this contemporary phenomenon by studying it in its real-life context [99] and by providing in-depth knowledge [100]. Consequently, we chose a qualitative method [101] and, more specifically, a multiple case study approach [99]. A total of four SMFB have been included in the case study and interviews with a variety of stakeholders have been conducted which in turn addresses on of the main criticisms case studies of SMFB face, namely the over-reliance on just owner-managers [100]. Hence, we were able to achieve access to multiple sources of evidence [99]. Moreover, regarding the family-external business succession this research access is advantageous as it reflects the successions' multi-level character [23]. Especially regarding family firms, Reay and Zhang [102] recommend an in-depth qualitative research as it allows for unearthing these firms' dynamics.

The four firms ("AUTO", "TOOLS", "FURNITURE" and "FOOD") have been small- or medium-sized family firms (as defined above) at the time of the interviews and based in either Austria, Germany or Switzerland. All interviews were held between the years 2012 and 2019 and the average duration were 68 minutes (across all AUTO interviews), 47 minutes (across TOOLS), 55 minutes (across FURNITURE) and 32 minutes (across FOOD). DiCicco-Bloom and Crabtree [103] state that qualitative interviews typically last between 30 minutes and several hours and the interviews held in the context of the present study fit into this time window. Table 1 below depicts the stakeholders that were interviewed across the four firms.

Table 1. List of individuals interviewed for this study

AUTO	TOOLS	FURNITURE	FOOD
New owner-manager	New owner-manager	New owner-manager	Incumbent owner-manager
Previous owner-manager	Previous owner-manager	Management employee	Employee
Employee 1	Employee	Consultant	
Employee 2		Trustee	
Former employee			
Capital provider			

The companies AUTO, TOOLS and FURNITURE underwent a family-external business succession through MBI a maximum of two years before the interviews. The FOOD business is currently undergoing the MBI process and is meeting interested parties as part of the due diligence. Therefore, it was mainly included in the examination of

proposition 1 and partly in proposition 2 based on the owner-manager's recollection of statements and indications made by interested parties. Table 2 below displays the main characteristics related to SMFB of the firms interviewed.

Table 2. Main characteristics of firms researched for this study

Information \ Case	**Furniture**	**Tools**	**Auto**	**Food**
Headcount post-buy-in	15-25	50-60	30-40	80
Annual turnover post-buy-in	2-10 M€	5-15 M€	25-35 M€	2-5€
Previous owner-manager's (incl. family) share of voting capital pre-buy-in	100%	100%	100%	100%
New owner-manager's (incl. family) share of voting capital post-buy-in	41%-49%	51%-61%	%51-61%	100% (desired)
Previous owner-manager's (incl. family) share of voting capital post-buy-in	Balance	Balance	Balance	0% (desired)
Capital provider's share of voting capital post-buy-in	41-49%	Balance	Balance	-
Generation of firm	3	2	3	1
New owner-manager's perception of firm as still a family firm (yes = still a family firm; no = no longer family firm)	No	Yes	Yes	-

Due to family firms' secrecy and the confidentiality of MBI transactions it is exceptionally difficult to study such successions while they occur [25]. Unsurprisingly, then, sampling took place on the basis of firms' availability and willingness to participate in the study after they were contacted by the researchers. Related to this, in the case of AUTO, FURNITURE and TOOLS retrospective interviews and in the case of FOOD prospective interviews had to be held [de vaus]. Especially retrospective or quasi-longitudinal research makes it possible to reconstruct data that arose over a period of time by collecting it at one point in time, namely the time of the interview [104]. Interview participants were thus asked to recollect occurrences [104] which poses the danger of having an error of recall [105], [104]. This problem has been attenuated by including a variety of different interview participants as has been shown in table 1 [105].

A semi-structured interview guide was created and issues of validity and reliability were considered [99]. As for *construct validity*, in order to achieve as much plausibility as possible and in a way that fits the underlying qualitative approach, we developed reproducible indicators related to the construct of digitalization. We follow Parviainen et al. [29] and divide the construct into three components: activities related to (i) internal efficiency, (ii) external opportunities and (iii) business models. Based on these components we found a valuable inspiration for indicators of digitalization with Neumeier et al. [76] and Bollweg et al. [77]. Stemming from the exploratory nature of this study, we follow Geider [106] in that we did not over-specify the indicators but rather created them in order to guide our collection and analysis. The complete list of indicators can be found in attachment A. Moreover, next to the utilization of multiple sources of evidence, all interviews were tape-recorded and transcribed completely to prevent a loss of evidence [99]. All interviews were held in the interviewees' native languages (German). In total, around 340 pages of

transcription were generated and imported into MAXQDA for coding purposes. Overlying categories that were found were compared across cases [107] and assigned to the causal propositions, if deemed relevant [108].

As to *internal and external validity*, this study is not perceived as capable of achieving a generalizability of its results owing to its exploratory nature [99]. However, by generalizing to the causal propositions developed in this study, we aim to contribute to theory building efforts as to digitalization during the process of family external business succession. So doing, achieving "internal generalizability" [100, p. 115] as a way of generalizing within the setting of the study becomes possible.

A case study protocol involving literature review, conceptual framework, interview schedule and credentials has been developed to achieve a more robust *reliability* [99]. Yet, due to the fact that non-disclosure agreements were signed with all firms, the publication of that protocol is not possible and interview anonymization and pseudonymization had to take place. However, appendices A.1 through B2. Demonstrate in exemplary ways how data collection, transcription, data analysis and the drawing of conclusions have been undertaken. In summary and reverting to the four ways of increasing validity stated by Maxwell [101], we conclude that there has been an intensive involvement with the study's participants (family firms), that rich data was created (around 340 transcribed pages), that triangulation took place based on a variety of interviewees and that a more robust multiple-case study approach was chosen as opposed to a single one.

5. Empirical results

The empirical section presents and analyzes data in the light of the research proposition developed above.

5.1 Examination of proposition 1

A family-external business succession through MBI took place in AUTO, TOOLS, FURNITURE and is the desired way of succession in the ongoing sale process of FOOD. In most cases, financial and legal topics dominated both the MBI preparation by incumbent owner-managers and the due diligence conducted by their potentially new counterparts at this point in time (and in the case of FOOD interested parties). In the AUTO case the interested new entrepreneur laid his due diligence focus on getting to know customers, travelling to industry fairs and drafting financial and especially cash-flow related budgets for AUTO's future. As he acquired the company in conjunction with a provider of capital, lawyers and financial experts at this capital provider conducted the main financial, legal and taxi due diligence. Given AUTO's sound financial results in recent years the new owner-manager's main concern was related to funding the MBI and to continuing with existing customers. There was hardly any evidence of digitalization playing an important role of AUTO's pre-buy-in phase, either for the incumbent or new owner-manager.

For TOOLS, however, the interested new owner-manager did include digitalization-related topics in his study and due diligence of the company. This was mainly due to outdated processes and an aging workforce at TOOLS which led the new owner-manager to draft a plan for the rejuvenation of the company. The digitization of processes such as accounting, or the introduction of an electronically accessible management information system were his main concerns. Thus, especially internal efficiency-related indicators were found in the case of TOOLS' interested new owner-manager. The incumbent one, however, made it clear that she was chasing exactly one goal: to sell the company. In the months prior to the start of the MBI process there was no dealing with an update of processes, channels or other digitalization-related issues.

Nearly the same applied to FURNITURE where the incumbent owner-manager was no longer the acting party due to health issues. Rather, his external trustee was entrusted with the task of selling the company. As this trustee is an accountant by nature, he did not influence the company's operations which were delegated to employees which in turn did not have much budget during the whole succession process. Much was hanging in the balance for FURNITURE until a new owner-manager was found. Within the due diligence, the interested new owner-manager was mainly looking at the overall market of FURNITURE and customer developments together with financial and tax-related reports. When it comes to the technical infrastructure of FURNITURE, he indicated a reliance on oral assertions made by the trustee,

such as concerning the quality and age of computers. In hindsight he was negatively surprised about the outdated technology used in FURNITURE, about missing computer passwords and a lack of software licenses.

Regarding FOOD, the current owner-manager's main task in the pre-buy-in phase has been the upgrade of the company's production facility. This included purchasing more modern manufacturing equipment which could be programmed and connected to a production planning software. Within this context, the modernization of FOOD's production meant that its owner-manager needed to look at the internal efficiency side of digitalization, namely the introduction of a software to streamline and connect planning and production services. Having said that, according to the incumbent owner-manager's statements the parties interested in acquiring FOOD have been quite uninterested in its digitalization activities and mainly focused on customers and the company's financials. It must be noted that at this stage there were no additional meetings scheduled between FOOD's owner-manager and interested parties, which implies no further opportunities for interested parties to address this issue. As FOOD's owner-manager put it with regards to digitalization: *"I can't say it was discussed in detail or that they even asked about it at all. In principle the production expansion has been the main topic." (FOOD's owner-manager; translated and paraphrased from German)*

Table 3 below provides an overview of the findings related to proposition 1. In summary, we find some preliminary support for our first proposition in that for AUTO's, TOOLS' and FURNITURE's incumbent owner-managers digitalization played a minor role at best in the pre-buy-in phase. For AUTO, FOOD and FURNITURE the same can be applied to the potentially new owner-managers and interested parties. They were found to be mainly interested in classic due diligence issues such as financials and customers. However, in the cases of TOOLS and FOOD we have found some evidence of instances where digitalization-related topics are part of the pre-buy-in phase. We conclude that such instances happened due to a concrete and specific situation in these cases, either the status quo of an organization (TOOLS) or changes to facilities or processes being made and also involving some degree of digitalization (FOOD). Therefore, we reason that proposition 1 needs to be modified as follows:

P1 (modified). *Small- and medium-sized family businesses' incumbent and new owner-managers either focus less on digitalization-related areas in the pre-buy-in phase or only within the context of related issues compared to classic and standalone due diligence topics.*

Table 3. Findings related to proposition 1

Case	**Owner-manager**	**Findings regarding proposition 1**
AUTO	Incumbent	low (mainly as part of usual IT activities which were delegated to staff anyway)
	New	low (focus on bidding process, market environment and customer development)
TOOLS	Incumbent	non-existing (full focus on selling the firm and no change in dated, paper-based processes)
	New	moderate (as part of concept how to renew the firm's aging infrastructure and workforce)
FURNITURE	Incumbent	non-existing (absence of owner-manager, trustee initiated and conducted the MBI)
	New	low (revelation in post-buyin phase only of age of computers)
FOOD	Incumbent	moderate (focus on upgrading production facility including introduction of production software)
	Interested parties	low (hardly relevant in meetings with interested parties, focus on production facility)

5.2 Examination of proposition 2

Our second proposition states that in the post-buy-in phase, new owner-managers will focus more on internal efficiency-related areas of digitalization. Indeed, we found resounding support for this proposition. In all cases nearly all issues concerning digitalization right after the new owner-managers took over related to internal efficiency. These issues ranged from simple considerations such as reviewing licenses and the availability and distribution of IT passwords (FURNITURE), to the ending of paper-based accounting processes in favor of an introduction of a more electronic way of doing things (TOOLS) to mere updates in processes in the cases of FOOD (based on indications of interested parties in the due diligence meetings) and AUTO. It becomes apparent that nearly all these actions concern firms' back-end systems and processes as well as the overall working style within organizations. TOOL's managerial employee stated a priority in the post buy-in phase and regarding the firm's accounting processes as follows: *"They used to work like there were no computers in the whole world. (…) And this was among the first processes that we modernised." (translated and paraphrased from German)*

FURNITURE's new owner-manager also prioritised relatively mundane, i.e. process- and exploitation-related topics in the immediate post buy-in phase: *"Let's take the simple example of licences in the IT department. Which employee has got a computer? And which computer is equipped with all licenses necessary to operate it properly? (…) All this basically constitutes a properly working IT infrastructure. And I've been unlucky and had to modernize it all." (FURNITURE's new owner-manager, translated and paraphrased from German)*

Thus, the indicators relating to the internal efficiency side of digitalization were found throughout all four cases. Additionally, there was no indication of concrete actions regarding external opportunities, such as customers or sales channels, or business models. Table 4 below summarizes our findings with regard to proposition 2.

Table 4. Findings related to proposition 2

Case	Findings regarding proposition 2	Immediate post-buy in focus
AUTO	slight modernisation of back-end (more digital processes, more KPI tracked digitally)	processes, systems
TOOLS	introduction of digital way of working in the first place in back-end (getting rid of paper-based accounting, hiring first ever IT person)	processes, systems
FURNI-TURE	strong modernisation of backend (review and purchase licences, upgrade computers, make known passwords in case of absence)	processes, systems
FOOD	according to meetings with interested parties: slight modernisation in processes	

5.3 Examination of proposition 3

As we have seen, new owner-managers involved in this study focus first on digitalization topics related to internal efficiency after having taken over their new companies. Proposition 3 indicates that despite their focus on such efficiency matters, they will start considering aspects of digitalization that are more long-term in nature (external opportunities and business models). As table 5 below demonstrates, we indeed find support for this proposition across all four cases. While new owner-managers were busy improving their firms' internal activities, they drafted visions and strategies of how to approach customers in a more digital way through their website (TOOLS). This connects well to the indicator developed in order to measure a more digital way of customer interaction. Similarly, the combination of FURNITURE's existing, analogue products with technology has been found a concern for its new owner-manager, thereby corresponding to the indicator that is linked to the creation of new and more digital products. AUTO's new

entrepreneur also indicated a desire to better involve technology with the company's sales undertakings. Moreover, AUTO's new owner-manager turned out to have some concrete business model-related visions and even a specific company that he likes to use as some sort of role model for AUTO's digitalization. This company is operating in a different industry and AUTO's new owner-manager has been impressed by this firm's high degree of digitalization. Additionally, FOOD's incumbent owner-manager reported on statements by interested parties regarding the introduction of a production system which takes into account customer preferences as opposed to the firm's current top-down approach. In doing so, the firm's new payment system would automatically interpret certain customer preferences based on their purchases of certain food products (e.g. more customers purchase option A compared to B). These findings would then be imported in the production system, thereby affecting the purchasing of raw materials and the subsequent manufacturing of particular food products.

Table 5. Findings related to proposition 3

Case	Findings regarding proposition 3
AUTO	Plans for new customer segments, horizontal expansion of know-how towards new industries; utilization of synergies between technology and sales
TOOLS	Creation and utilization of Internet-based sales channel (website)
FURNITURE	Combining technology and ergonomics in future products
FOOD	Introduction of digital payment system, production based on digitally available customer preferences

6. Discussion of results

The wave of digitalization [1] that sweeps across nearly all companies worldwide is of particular concern in small- and medium-sized family firms [35], [36], [40], [38], [2]. What is more, many of those SMFB will need to be transferred to new owner-managers in the years ahead [24], [25], [26], [27]. As such processes of transferring the businesses to outside owner-managers have been found to go along with managerial interruptions [12], the combination of the two contemporary issues of digitalization and family external business succession is the main concern of this exploratory study. In doing so, we built upon Hopkins et al. [89] and Sherer et al. [90] who argue that digitalization within the context of business succession and due diligence is a relevant, yet rather new and often neglected area. We therefore attempted to shed some initial light on how digitalization is considered by incumbent and new owner-managers during a business succession process. As business succession has been found to run along the lines of a process [59] we divided the succession in a pre- and post buy-in phase and explored how digitalization is being considered in each of these phases.

Regarding the pre-buy-in phase we find that digitalization either played a less important role for interested new owner-managers or when it played a more pronounced role it was due to its connection to an issue of major concern. Such major concerns included an outdated organization which the new owner-managers hoped to improve by introducing certain facets of digitalization as well as the concern of setting up a new production process and connecting it to a software-based planning. Beyond that, classic aspects of due diligence such as finance, tax and customer issues were prioritized by the new leaders. What is even more relevant in this phase is the digitalization-related behavior of incumbent owner-managers. With the exception of one case, we find that the remaining three cases were characterized by incumbent owner-managers not initiating any digitalization efforts at all in the pre-buy-in phase. This adds to Taiminen and Karjaluoto [38] who report on reasons for delaying the introduction of tools or processes related to digitalization. Now, one could argue that the firms already employed state of the art digital processes or tools, but this is – according to the available data – not the case. On the contrary, in some cases whole departments still ran on a paper

basis and continued to do so during the post-buy-in phase. Our findings also relate to Cravotta and Grottke [2] who state that family firms need to prepare themselves for long-term changes brought upon them by digitalization and that those changes also affect these firms' operational activities. These changes also touch upon operational matters [109], [110] which is relevant insofar as business succession is accompanied by very hands-on issues, as demonstrated in this study's results. We find that the succession process can delay the introduction of those changes and therefore a prolonged family-external business succession demonstrates a challenge for SMFB that could impede their competitiveness. Bollweg et al. [77] come to a similar conclusion concerning digitalization in SMFB even in non-succession times. Our study also supports Hopkins et al. [89] in that we too find that digital assets such as software licenses were partly neglected in some of the firms' due diligence. This in turn created noteworthy obstacles for successors in the post-buy-in phases. Moreover, we can partly support Sherer et al. [90] who state that digitalization plays a still incomplete role in due diligence processes.

Additionally, our findings support propositions 2 and 3 which indicate that new owner-managers focus first on digitalization-related aspects of internal efficiency while at least strategizing on more long-term issues such as external opportunities through digitalization or even transforming their business models. Starting in the immediate post-buy-in phase, our reasoning that new owner-managers will first look at improving day to day issues and focus on enhancing efficiency and the smooth running of operations was supported. We based our assertions on a body of literature that points out the importance of down-to-earth issues such as cash flows, customers or processes in the post-buy-in phase for new owners-managers [59], [32], [60], [61], [15]. Utilizing the three layers of digitalization according to Parviainen et al. [29] we indeed find that internal efficiency is of priority to new owner-managers in the immediate post-buy-in phase compared to external opportunities (e.g. relating to customers) or the transformation of business models.

However, addressing proposition 3, such external opportunities and business models were part of new owner-managers' more long-term and visionary thoughts in the post-buy-in phase even if no concrete actions were taken. Thus, our findings conform to Epstein [93] in that also in MBI transactions involving SMFB and addressing digitalization, leaders think about long-term strategies. Such thoughts correspond to evidence that awareness of digitalization is on the rise in small- and medium-sized firms [96], [97]. In fact, our study adds to this research the finding that external business successions demonstrate one opportunity for the rise of such awareness as new owner-managers approach their new companies with fresh ideas and visions. It therefore supports the assertion of business succession being an engine for innovation and exploration [98] and not only in general, but specifically in the context of this study's focus on digitalization. These more strategic attempts of rejuvenation, however, are more long-term in nature.

Our study's findings indicate that during the process of external business succession in SMFB, digitalization efforts play only a secondary role compared to more pressing matters for both incumbent and new owner-managers in the pre-buy-in phase. As to the post-buy-in phase, internal efficiency was found to be the main dimension of digitalization that the new leaders turned to. Table 6 summarizes this paper's main findings which also have some serious implications for policy makers, owner-managers and researchers as we will point out in the next section.

Table 6. Summary of main findings

Phase	**Main findings**
Pre-buy in	Low to moderate levels of new digitalization activities; indication of delays in introducing digital infrastructure in the wake of succession; low concern with digital issues in due diligence processes
Post-buy in	Main focus on efficiency gain from digitalization; awareness of longer-term and strategic use of digitalization

7. Limitations and implications

This study is exploratory in nature and involves four small- and medium-sized family firms as part of its multiple case study approach. Our data touches on a research topic that is still under-researched [10], [15], [39], [40]. By developing, testing and in part modifying three causal propositions we contributed findings that can now be further substantiated in future research. Also, our study touches upon the open debate about realizing ambidexterity of both exploration and exploitation in the sense of March [92], particularly in times of digital transformation and disruption in the realm of SMFB.

Yet, our research comes along with several limitations. First, its exploratory case study approach translates into the impossibility of generalizing our findings across SMFB. As Eisenhardt and Graebner [107] note, by the replication logic it becomes possible to build more robust theories from case study research and this implies further research in this area. Second, we turned to entrepreneurship theory for the utilization of a theoretical lens and we needed to maneuver some level of abstraction in the operationalization of constructs and in the creation of this study's conceptualization. Third, more focus can be given to family firms' idiosyncrasies [8] and to these firms' specific situations and points of origin regarding digitalization even though this is challenging in the difficult-to-research area of external business succession [14], [23]. Fourth, our empirical investigation has been based on a retrospective, quasi-longitudinal approach and this entails a variety of limitations such as the possibility of errors of recall [105]. Additionally, our qualitative case study method involving interviews poses the threat of having biases, such as towards the researcher (from the participants' point of view) or towards data (from the researchers' point of view; [101], [105]). Finally, our study is limited to the 'DACH' region of Europe and further research in other geographical areas is needed as cultures or priorities of family firms in those regions might differ.

In light of these limitations, further research is deemed necessary in this economically and societally important area of SMFB and digitalization. We encourage future researchers to attempt to gain in-depth access to family firms, which our study has shown is possible given a level of patience and persistence. In doing so, researchers will find ample opportunities in studying digitalization activities of SMFB during their business successions. More research is needed in order to specifically measure these firms' point of origin when it comes to their degree of digitalization and the specific effects succession processes have on the status of digitalization after a, in many cases, years-long succession process. In case of more researchers finding that certain aspects of digitalization are postponed or neglected during such processes this has serious consequences for the competitiveness of this firms – and, consequently, for the health of the economies of Austria, Switzerland and Germany which all depend heavily on these SMFB. Therefore, policy makers are well advised to closely follow this topic and, in case future research supports our findings, develop appropriate measures of support for such firms and their digitalization in times of succession. To practitioners our findings indicate that during due diligence processes there are tangible benefits of including digitalization-related areas in their investigation next to the more classic topics of finance, tax or customers.

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Appendix

A.1. List of codes and indicators for empirical investigation

Level	Codes	Indicators	On the basis of:
Ext. Opp.	PRSV	Creation of digital products or services	Parviainen et al., 2017; Kollmann, 2016
Ext. Opp.	PRSVQA	Improvement of digital products/services quality	Neumeier et al., 2017; Henriette et al., 2015; Kollmann, 2016; Bollweg et al., 2016
Ext. Opp.	CUCO	New ways of digital customer interaction	Neumeier et al., 2017; Henriette et al., 2015; Kollmann, 2016
Int. Eff.	PROCIM	Change to digital of internal processes	Kollmann, 2016; Vieru, 2015; Bollweg et al., 2016
Int. Eff.	ORGIMP	Tweaking/introducing digital changes in organisation	Kollmann, 2016; Neumeier et al., 2017;
Int. Eff.	SYSTDIG	Creation or improving digital systems, tools or reportings	Kollmann, 2016; Vieru, 2015
Int. Eff.	STTE	Staff or technical equipment changes related to digitalization	Kollmann, 2016; Henriette et al., 2017; Vieru, 2015
Bus. Mod.	BUSMO1	Diversifying the business	Henriette et al., 2015; Parviainen et al., 2017; Neumeier et al., 2017
Bus. Mod.	BUSMO2	Vision for change in business models	Henriette et al., 2015; Kollmann, 2016; Parviainen et al., 2017; Neumeier et al., 2017
Bus. Mod.	BUSMO3	Actual changes in business model	Henriette et al., 2015; Parviainen et al., 2017; Neumeier et al., 2017
Misc	MISC1	Others	

A.2. Exemplary illustration of coding and data abstraction from semi-structured interviews

Document	Code	Segment (translated)	Phase	Abstraction
AUTO Interview CP	RME1	To some extent AUTO was being run by the two managerial employees. So they didn't always need to go back and forth to the owner-manager or patriarch, but were in many areas free to take decisions. Not in all areas, but in important operational ones.	Pre	Delegation to employees Same level of conduction as in non-succession times
AUTO Interview CP	RME1	That made the whole succession easier, because AUTO was like on auto-pilot during the succession negotiations.	Pre	Delegation to employees Same level of conduction as in non-succession times
AUTO Interview CP	RE1 CO5	He [new owner-manager] talked to almost all employees after taking over. And when he took over management he also developed a future strategy for AUTO and he did this will the important managerial employees. So he did set the frame work but then he also discussed with his staff about their ideas and recommendations. And that was something that was well received with the staff as that did not happen previously [with old owner-manager before succession].	Post	Change in post- compared to pre-succession phase

B.1. Exemplary illustration of transcription of audio file into Word document (translated)

I: If I understand you correctly the new owner-manager did communicate that there was pressure to improve the firm's financials rather quickly? #00:23:31-0#

B: Yes, well, the pressure was originating from the new owner-manager of course. It's just like that. But the AUTO industry runs on a development cycle of two to three years, minimum. That means you won't achieve much in the short-term with such pressure. #00:23:48-3#

B: So with these development cycles some big items like supplier contracts or so are fixed for two or three years. You can't just re-negotiate them overnight. #00:24:01-0#

B.2. Exemplary illustration of data analysis based on transcription and subsequent data abstraction

	Pre-buyin digitalization efforts			
Company	AUTO	TOOLS	FURNITURE	FOOD
Evidence reg. Pre-buyin digitalization efforts (previous / existing owner-managers)	- IT-related employees were responsible for improving processes - Process improvements occured in terms of efficiency, not in terms of overhauling them completely based on new business models - Previous owner-manager not too much involved, delegated task to IT staff; focus of owner-manager not on IT or digitalization or new business models - AUTO needed to have industry-specific IT systems in place in order to deal with car manufacturers and their supply chains; this was seen as AUTO's IT and digitalization framework	- Pre-buyin, there was hardly any focus in IT or digitalization - Accounting was still mainly done using paper invoices and on paper - No meetings or concerns regarding digital shifts in the tools selling industry - Previous owner-manager had sole focus on traditional selling methods - IT landscape of TOOL meant basic things such as a website or email address	- Hardly any focus digitalization pre-buyin, as the previous owner-manager was largely absent and the managerial employees did not have budget or leeway to initiate projects - Essential commercial aspects such as cash flows and accounting were very much the focus of the managerial employees pre-buyin - FURNITURE had a basic IT landscape in place pre-buyin, for instance using online product catalogues to order products from suppliers. There was no efforts to change or improve them or add to them in terms of digitalization during the pre-buyin times.	- In FOOD's pre-buyin phase there were activities to overhaul ist product facility and introduce "smart" processing machines or machines for which data could be extracted (e.g. how much output in electronic terms). - For FOOD these efforts were important because of industry shifts which the owner-manager discovered and wanted to realise in FOOD in order to make it more attractive for potential successors

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

IT projects success factors: a literature review

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C. Iriarte, S. Bayona, "IT projects success factors: a literature review", *International Journal of Information Systems and Project Management*, vol. 8, no. 2, pp. 49-78, 2020.

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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IT projects success factors: a literature review

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Abstract:
Information Technology (IT) projects are enablers of organizational transformation and business growth. Despite the contribution of methodologies and frameworks for project management, the ratio of failed IT projects remains high; then, studying critical success factors of IT projects persist as an essential issue for researches and practitioners. This paper presents a systematic literature review focused on compiling and synthesizing project success factors in IT projects. The literature search was conducted using primary journal articles until 2017. All studies agree on the relevance of studying the critical success factors in IT projects given their particular characteristics. The results indicate there is no clear definition of project success concept; our review consolidates the IT success criteria into time, budget, project management, system quality, user satisfaction, and economic value. Also, there a vast and overlapped list of factors; so, this research proposes a structure that synthesizes the most referenced critical factors that have in common soft attributes as involvement, support, communication, and commitment. Findings reinforce the relevance of soft skills in IT project teams.

Keywords:
project success; IT project; systematic review; success factors.

DOI: 10.12821/ijispm080203

Manuscript received: 29 August2019
Manuscript accepted: 19 January 2020

1. Introduction

Information technology (IT) projects serve as vehicles of transformation and business growth. It has been observed that annual global investment in information technology is permanently increasing. Gartner-Inc estimates that in 2019, it will reach 3.79 trillion dollars [1]. These investments are made to contribute to the achievement of organizational aims and objectives [2]. IT enables multidimensional IT-based change in organizations, and they are increasingly configured oriented or based on projects [3, 4].

Even though progress has been made in project management practices and methodologies, the high ratio of failure in IT projects continues. Project methodologies and frameworks have contributed to better project achievements and to help address low success rates using project-related knowledge [5, 6]. However, over time, the IT failure rate is still high. Standish Group reports that 31.1% of the projects are classified as failed, which means they were abandoned or canceled, and 52.7% are completed over cost, over time, and/or lacking promised functionality [6]. So, it is therefore vital to find out what makes the difference in project results and what are the critical factors.

Critical success factors have been studied extensively with specific approaches, and the lists of critical success factors that have resulted are also vast. Some authors focused on a specific methodology [e.g., 7, 8], technology [e.g., 9, 10], stakeholder perspective [e.g., 11, 12, 13], specific group of factors [e.g. 9, 14], or others. To a large extent, this long list is since each project is unique. Although project methodologies seek to be general for all types of projects, there is a coincidence in the authors in pointing out that the different particularities of the projects influence success. Belassi presented the variation in the criticality of factors among the industry sectors; the author demonstrated that there are sectors in which some factor is very critical while in another sector it is not relevant [15]. This idea, more recently reinforced by project studies, has adopted a contingency approach that indicates that project performance increases if the contextual factors are aligned with the structural factors of the organization [16-18]. It has been pointed out that the context, type, history, and nature of the projects are elements that should be considered [18, 19].

Project success is intensely studied in general project management literature, and these studies have contributed to our understanding of the phenomenon. However, it is convenient to explore the success in the context of IT projects, given the particularities of high complexity, uncertainty, and high risk of the more significant number of information technology projects. There are no studies that summarize, evaluate, and interpret the relevant literature on these factors transversally. While there are literature review studies about project success [20, 21], there are not literature reviews in the IT project field. In IT literature, studies are found [e.g., 22, 23] who make contributions through literature review with a focus on software development rather than projects; therefore, they present a technical approach more than a management one.

To help fill this gap, a Systematic Literature Review (SLR) of IT project success was performed focusing on critical success factors expressed as attributes (e.g., involvement, commitment, expertise, quality) that apply on project objects (e.g., users, sponsor, schedule, methodology). Based on a rigorous systematic review methodology, 39 articles were identified and analyzed, summarizing the criteria to define success and its factors, as well as synthesizing the main categories of factors.

This research contributes to the literature by identifying opportunities for future research in the field of critical factors. This study is also useful for managers since it can guide them in their decision-making processes, project organizing, resource assignment, monitoring, and control. Finally, it is helpful for project managers to identify critical success factors and act according to them.

This paper is structured as follows. Section 2 summarizes the previous literature on the subject. Then, the research question and methodology are presented in section 3. The results and discussion are developed in sections 4 and 5, respectively. Finally, section 6 presents the conclusions.

2. Background

2.1 Project success

No clear definition of the concept "project success" was found. It has been defined in a range of different ways [24-26]. Many authors conceptualize success grounded in the criteria of success, criteria in which there is no consensus, the most traditional is the so-called "iron triangle" comprising cost, time, and quality [24, 25, 27-29]. Baccarini [30] presents project success as a core concept in project management, identifies two components that define a successful project: successful project management and successful product of the project. In another stream, "success" is corresponding to the efficiency and the effectiveness of the project. The efficiency understood as the maximization of output for a given level of resources; the effectiveness directed to the achievement of goals or objectives [31].

Project Success concept is often based on the different perceptions of each stakeholder depending on the moment the project is found; it is usual to find that the same project is considered successful by some and a failure by others. Lim and Mohamed [32, 33] explain that a project impacts a different way to each element of society, and each stakeholder such as the individual owner, developer, contractor, user, the general public, each of them has a different perspective. The perception of the stakeholders rather than being a global perspective is due to a perception of the achievement of their own objectives [34-36].

The existing theory of project success is mainly relying on the work done by Pinto and Slevin. The study aimed to construct a more general and more widely accessible measure of project success applicable to a variety of organizational projects. Success comes from criteria linked to the project (e.g., time, cost, and the performance of the project); as well as criteria related to the client (e.g., such as use, satisfaction, and effectiveness) [37].

In contrast to the search for a general measure of success, more recently, the project contingency theory (PCT) has emerged linking project management methods and the project context [16]. Contingency theory suggests that the structural factors in organizations should suit the contextual factors to increase performance [17]. Based on contingency theory, Shenhar, who has conducted several studies based on contingency theory, proposes four bases to analyze projects (NTCP): "Novelty", how intensely new are crucial aspects of the project?; "Technology", where does the project exist on the scale from low-tech to superhigh-tech?; "Complexity", how complicated are the product, the process, and the project?; and, "Pace", how urgent is the work? Is the timing "normal, fast, time-critical or blitz"? [38].

The project success criteria are the conditions that a project must meet to determine if it is acceptable; this list of criteria varies from project to project. In literature we found the concept of the "iron triangle", "triple constraint" or "golden triangle" as a representation of the essential criteria for assessing project performance; it means the project is delivered by the due date, within budget and with quality, performance or scope [25, 27, 39]. At the same time, as the use of the triangle, other less used concepts are found, such as "virtuous square of criteria" or "quadruple constraint" (which include customer satisfaction). Recently, Pollack indicated the iron triangle concept is still valid; there is an agreement in two vertices of the triangle: time and cost; and for the third vertex, the most common use is quality following by scope, performance, or requirements [40]. Satisfaction is a perception criterion also included in the literature. For example, Westerveld, under the term "appreciation" shows the relevance of it by defining six categories, five related to satisfaction: project results (Budget, Schedule, Quality), appreciation by the client, by project personnel, by users, by contracting partners and by stakeholders [41]. Is becoming constant the inclusion of benefit concepts, such as benefit to the client, to the organization, to the stakeholders, support to the strategy, and business outcomes, such as information-processing benefits, effects on business operations, or impact on business performance [e.g., 42, 43].

In conclusion, project success is a multi-dimensional concept depending on criteria, stakeholder perception, the context, and the phase the project is found.

2.2 Project success factors

The literature on success factors is ample. The most cited author regarding success factors is Cooke-Davies who presents twelve factors to project management success, to a successful individual project and consistently successful projects [28]. Another facet of project success that is important to establish is time frame [44]. Pinto & Slevin give fourteen critical success factors and analyzes the most relevant for each stage of the project [45]. Sudhakar collects eighty factors [46] and presents a model explaining interaction among groups of them. To avoid problems associated with critical success factors that give rise to the criticisms, Fortune & White present twenty-seven critical factors collected from literature and map them onto components of the formal system model used as a framing device to deliver the benefits of taking account of critical success factors [47].

Regarding the project success factors categories in literature, there are several lists of them; one of the most referenced readings in terms of factor grouping is Belassi & Tukel [15]. They studied success factor collected from literature, described the impact of these factors on project performance and grouped the factors into four areas: factors related to the project, factors related to the project managers and the team members, factors related to the organization and factors associated with the external environment [15]. Later, Yeo presents three groups: two related to the managerial and organizational context and one related to the development of the project [48]. Westerveld categorizes the factors in seven areas: leadership and team, policy and strategy, stakeholder management, resources, contracting, project management and external factors [41].

2.3 IT Project

PMI defines a project as "a temporary endeavor undertaken to create a unique product, service, or result" [49]. Information Technology (IT) is the technology used to acquire and process information in support of individual and social purposes. It is typically instantiated as IT systems - complex organizations of hardware, software, procedures, data, and people, developed to address tasks faced by individuals and groups, typically within some organizational setting [50].

Another relevant term is "Information System" (IS) can be defined as a working system whose processes and activities are devoted to processing information, that is, capturing and transmitting, storing, retrieving, manipulating, and displaying information. Thus, an IS is a system in which human participants or machines perform work (processes and activities) using information, technology, and other resources to produce informational products or services for internal or external customers [51].

Combining project characteristics and IT objectives, Bannerman presents an "IT project" definition, IT projects are discrete and unique activities that serve as vehicles of multidimensional IT-based change [52].

The International Council on Systems Engineering (INCOSE) points out a factor that characterizes technology projects: Complexity. Complexity is a characteristic of more than just a technical system being developed. It is often created by the interaction of people, organizations, and the environment that are part of the complex system surrounding the technical system [53]. IT projects are different from and potentially more difficult than other engineering projects as they are characterized by high complexity and high chances of project failure. Some characteristics make them different from other engineering projects and increase the chances of their failure [54].

Most of the IT project characteristics are related to the fact that IT projects involve software. IT projects are often poorly defined, market pressures demand delivery in the shortest time. The rapid pace of technological progress in IT hinders expertise. The tendency to write new software code to perform well-established functions decreases reliability. IT projects involve numerous iterations and continuous interaction and their work are highly interdependent [54]. In addition to complexity, The Royal Academy of Engineering and the British Computer Society mentions lack of constraints due to the immateriality of the software, the software is effectively invisible, there is a visualization problem source of many potential IT project failures, the uncertainty that is generated because many IT systems seek to undertake or increase tasks previously performed by people; the majority of IT projects are undertaken to deliver some business or process change and require an understanding of the company and the processes concerned [55]. IT projects

contain a higher degree of novelty than other engineering projects. In particular, IT projects related to product innovation development are extremely complex, risky, and expensive endeavors [56].

In this study, IT projects include infrastructure, outsourcing, information systems (IS), and related projects as Enterprise Resource Planning (ERP) and Customer Relation Management (CRM). It is noticed that researches use the terms IS (for development or implementation) projects, IT projects, software (development) projects indistinctly.

2.4 IT Project success

In the IT project world, success studies were based on information systems success studies; Thus, several authors use TAM and TAM2 [57, 58] as their basis, these models explain perceived usefulness and usage intentions in terms of social influence and cognitive instrumental processes. Another group of studies related to the measurement of information system success are based on DeLone & McLean IS Success Model; authors suggest an interactive and taxonomy model as a framework for information system success model [59, 60]. These information system studies have an orientation that links success to the product and user satisfaction.

The approach that includes project management success and information system success, is presented by studies that were based on the sum of the project theory and the theory of success of information systems [43, 61, 62].

Some authors, based on critical success factors (CSF) concept, define the few critical areas of activity in which favorable results are absolutely necessary for a particular manager to reach his or her goals [63].

A smaller number of authors have been based on other theories. Based on attribution theory, which represents an extensive examination of the perceived causes that many apply to events involving themselves or others [64]. Based on analytic hierarchy process (AHP), a method that uses a hierarchic structure to present a complex decision problem by decomposing it into several smaller sub problems, used to reflect the importance, or weights, of the factors associated to priorities [65]. Based on fuzzy cognitive maps (FCM) a modeling methodology for complex decision systems, which has originated from the combination of fuzzy logic and neural networks, describes the behavior of a system in terms of concepts such as entities, states, variables or characteristics of the system [66]. Based on grounded theory, theory in which insights emerge from the data rather than from researchers' preexisting theoretical concerns [26].

In the IT field, project success studies are carried out under the contingency approach. Critical success factors have been studied extensively with specific approaches. Some authors focused on a specific methodology [e.g. 7, 8], technology [e.g., 9, 10], stakeholder perspective [e.g., 11, 13, 26], specific group of factors [e.g., 9, 14], or others. It is noteworthy that the most studied type of project corresponds to ERP implementation projects, and more recently, there is a significant number of studies in projects that apply an agile methodology.

3. Methodology

To identify as much of the relevant literature as possible and to aim to present a fair evaluation of a research topic by using a trustworthy, rigorous, and auditable methodology, a systematic literature review appropriate for software engineering researchers were followed [67]. This study comprises three stages: planning, conducting, and reporting.

3.1 Research questions

The research questions are:

- RQ1: What is the definition of "IT Project Success" given by authors?
- RQ2: What are the critical factors for project success most referenced in IT project literature?
- RQ3: Which are the categories in which the critical factors for IT project success have been grouped?

3.2 Search process

The electronic databases searched in this review included those identified as relevant to Information Technology (IT): IEEE (Institute of Electrical and Electronics Engineers), ACM (Association for Computing Machinery); also, because IT is an interdisciplinary field, we looked in transversals databases: Scopus and Web of Science.

The search terms were constructed in four steps: 1) identification of key terms from the research question identifying the most appropriate terms, 2) identification of synonyms and acronyms, 3) terms combination using the "and" and "or" operators, and 4) adjust the search terms according to the terminology for each database.

Terms according to the research questions were included: "project success" and "project failure", since some authors study what must be done and others what should not be done, both looking at the success of the projects. To focus the scope in technology projects, "Information Technology" and "Information System" terms were used, followed by acronyms and synonyms like "IS", "IT", "ERP", "CRM", "HIS". Finally, finding answers to research questions, "factors" and "models" terms were introduced in the search. The final search strings used are shown in table 1.

Table 1. Search Strings

Source	Search string
IEEE Institute of Electrical and Electronics Engineers	("project success" OR "project failure") AND ("factors" OR ("Author Keywords": "models")) AND (("Author Keywords":"IT") OR ("Information Technology") OR ("Information System") OR ("software") OR ("ERP") OR ("CRM") OR ("HIS"))
ACM Association for Computing Machinery	((acmdlTitle:(+"project success") OR recordAbstract:(+"project success")) OR (acmdlTitle:(+"project failure") OR recordAbstract:(+"project failure"))) AND ((acmdlTitle:(+"factors") OR recordAbstract:(+"factors") OR (acmdlTitle:(+"models") OR recordAbstract:(+"models"))) AND(Title:(+"IT") OR recordAbstract:(+"Information Technology") OR recordAbstract:(+"Information System") OR recordAbstract:(+"software") OR recordAbstract:(+"ERP") OR recordAbstract:(+"CRM") OR recordAbstract:(+"HIS"))
Web of Science	(TI="project success" OR TS="project success" OR TI="project failure" OR TS="project failure") AND (TI=factors OR TS=factors OR TI=models OR TS=models) AND (TS="Information Technology" OR TS="Information System" OR TS=software OR TS=ERP OR TS=CRM OR TS=HIS)
Scopus	(TITLE-ABS-KEY ("project success") OR TITLE-ABS-KEY ("project failure")) AND (TITLE-ABS-KEY ("factors") OR KEY ("models")) AND (KEY ("IT") OR TITLE-ABS-KEY ("Information Technology") OR TITLE-ABS-KEY ("Information System") OR TITLE-ABS-KEY ("software") OR TITLE-ABS-KEY ("ERP") OR TITLE-ABS-KEY ("CRM") OR TITLE-ABS-KEY ("HIS"))

Several criteria were specified to select appropriate studies. These criteria are presented in Table 2.

Table 2. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Only journals will be included (books, doctoral papers, conferences are excluded). • Papers contain terms that match those defined in the search string. • Papers include the title, abstract, or content related to the topic. • Papers that included the study of factors. • Papers published in journals rated Q1, Q2, or Q3 in Scimago Journal Rank.	• Duplicated articles. • Papers in a language other than English. • Papers related to sectors other than IT. • Title and abstract review exclude articles that correspond to some specific success factors. • Exclude systematic reviews and meta-analysis. • Lessons learned reports based on expert opinion.

3.3 Search execution

Our search resulted in 920 potentially relevant articles (Fig. 1). Of these, 39 publications met our criteria.

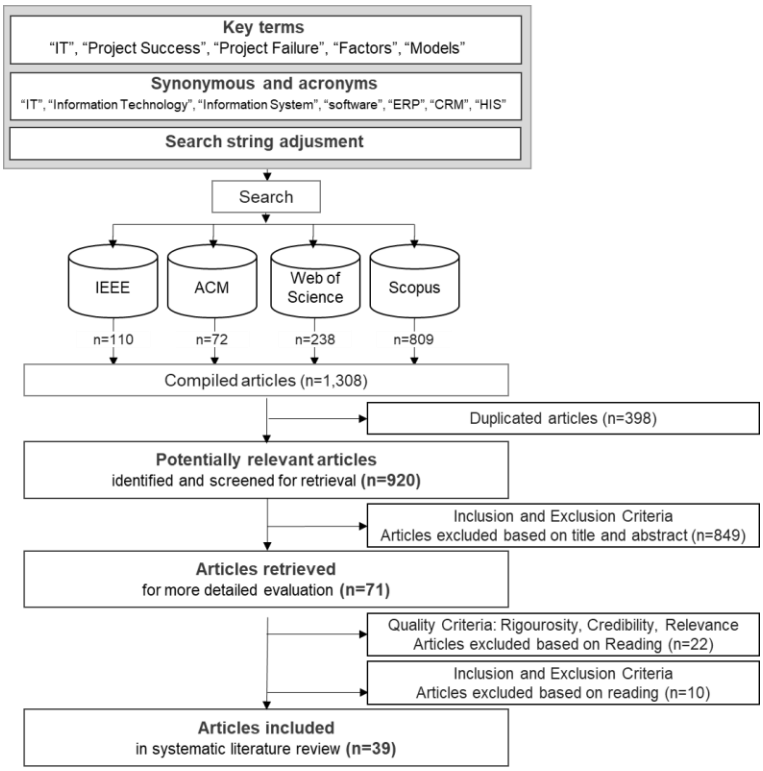

Fig. 1. Search Process. The process followed during articles selection and quantities found

The thirty-nine selected papers are listed in appendix A. In addition to the Scimago journal rank, as quality selection criteria, a quality assessment question list was defined to ensure alignment with the objective of this research. Each selected article will be evaluated according to (1) Rigor (quality of research methodology), (2) credibility (findings and conclusions are correctly presented and with a complete meaning), and (3) relevance (usefulness for the subject of our study). Eight questions cover the three criteria. The quality score ranged from 0 to 8. The scoring system used to determine the individual question score was: Yes (Y) = 1 point, Partial (P) = 0.5 points, No (N) = 0 points. The overall quality score was obtained, summing the eight individual question scores. Thus, the total quality score for each paper ranged between 0 (very poor) and 8 (very good). The quality questions and scores obtained from the included papers are listed in appendix B.

4. Results

All kinds of IT projects were found in the selected papers. Table 3 shows ERP is the most studied IT project type, followed by agile projects.

Table 3. Project Types Studied in IT Project Success Factor Literature

IT Project Type	Frequency	%
General	21	54%
ERP	12	31%
Agile	3	8%
CRM	1	3%
EIS	1	3%
Open-source	1	3%

The research approach used by authors is shown in table 4. The most significant number of studies is quantitative. The high number of studies are descriptive and explanatory. The analysis technique most used in the studies is the correlation analysis (24.4%) followed by the structural equation model with 14.3%. Other techniques are used, such as bayesian model, factor analysis, frequency analysis, among others.

Table 4. Types of Studies

Approach	No.	%	Type	N°	%
Quantitative	31	79%	Correlational	15	38%
			Descriptive	12	31%
			Explanatory	4	10%
Qualitative	5	13%	Case study	3	8%
			Interviews	2	5%
Quantitative & Qualitative	2	5%	Correlational & Interviews	2	5%
Conceptual	1	3%	Conceptual	1	3%

4.1 RQ1: What is the definition of "IT Project success" given by authors?

The types of definitions found are shown in figure 2; 30 of 39 authors did not specify a definition, and only 9 of 39 did a specific definition. Three authors did an intensional definition, providing a statement that establishes the essence of the concept, and six authors did an extensional definition (explaining the concept from a list of success criteria).

Three authors explicitly defined the 'Project Success' concept. "We define ERP project success as the use of such a project to promote effective deployment and enhance organizational effectiveness to which the project management efforts of the steering committee are crucial" [P10]. "The concept of 'success' was derived from a pilot study of practitioners and was 'defined' as (a) there is a project plan, (b) the project is well planned, (c) practitioners have a sense of achievement while working on a project, (d) practitioners have a sense of doing a good job (i.e., delivered quality) while working on a project, and (e) requirements are accepted by the development team as realistic achievable" [P13]. "Ensure successful competitive performance for the organization" [P36].

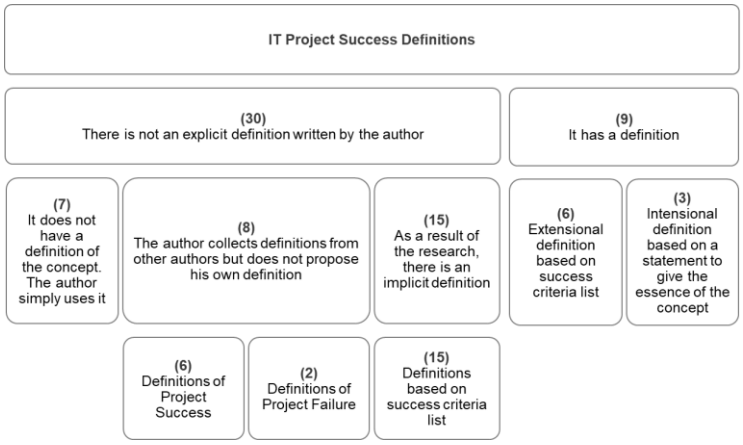

Fig. 2. Types of IT Project Success Definitions.

Several authors who defined extensionally based on success criteria included benefit and impact for the organization. "The success of project introduction is a multifaceted concept and, therefore, can be measured in various categories. These categories include introduction speed, visible and measurable business benefits, as well as the fast return of investments [P16]; "Our study defined success related to the extent that potential benefits were achieved, the costs associated with achieving those benefits, and the duration since going live [P27]. "Project success is defined as organizational impact and on time and on/under budget project completion" [P28]. "Success in ERP projects may be evaluated on traditional project-management metrics, such as on-time or on-budget performance, or based on business outcomes, such as information-processing benefits, effects on business operations, or impact on the business" [P30].

The authors do not agree on the same single definition of project success. Even thirteen authors who keep definitions linked to the iron triangle present some variant for the vertices; for the time vertex: time, schedule, adherence to schedule, within time, duration; for the cost vertex: cost, budget, adherence to budget, financial budget, within budget; for the third vertex there is a much more varied list. The list of criteria used in extensional definitions is shown in table 5.

Table 5. Project Success Criteria in Extensional Project Success Definitions

Process Performance	**Product Performance**	**Satisfaction**	**Benefits and Impact**
Time [P15], [P6], [P23], [P20]	Quality [P6], [P11], [P20]	User satisfaction [P1], [P15], [P26]	Benefits [P34]
On-time [P30]	Quality product [P1]	Customer satisfaction [P9]	Business perspective [P26]
On-time completion [P28]	Features [P23]		Economic value [P15]
Timelines [P11]	Functionality [P23]		Financial terms [P18], [P19]
Duration [P27]	Performance [P22]		Information-processing benefits [P30]
Cost [P6], [P27], [P11], [P20]	Product performance [P24]		Effect on business operations [P30]
Budget [P15], [P23]	System quality [P15]		Impact on business performance [P30]
On budget [P30]	Future needs [P19]		Business benefits [P16]
On budget completion [P28]			Return on investments [P16]
Under budget completion [P28]			Organizational impact [P28]
Scope [P11], [P20]			Potential benefits [P27]

Process Performance	Product Performance	Satisfaction	Benefits and Impact
Process efficiency [P9]			Process improvement [P19]
Process performance [P24]			
Project management [P15], [P22]			
Project metrics [P26]			
Project performance [P29], [P12]			

In the articles reviewed, we found ten authors who focus their study on determining success criteria. These studies take some initial relationship of success criteria and, by some method, establish the validity of them. Papers that consider success as a global variable or papers that use success variables without developing any validation on these variables were not included.

Table 6. Project Success Criteria Variables

No.	Success criteria	[P14]	[P7]	[P9]	[P10]	[P29]	[P15]	[P26]	[P13]	[P17]	[P12]	Times criteria
1	Customer satisfaction	X		X						X		3
2	User satisfaction				X		X				X	3
3	Adherence to budget	X				X						2
4	Adherence to schedule	X				X						2
5	Information quality				X		X					2
6	Process efficiency	X		X								2
7	System quality				X		X					2
8	Addresses a need		X									1
9	Budget		X									1
10	Business value							X				1
11	Competitive advantage									X		1
12	Contractor satisfaction	X										1
13	Customer is satisfied		X									1
14	Duration										X	1
15	Efficient task operations					X						1
16	Financial budget										X	1
17	Functionality		X									1
18	Goals achievement										X	1
19	Individual impact				X							1
20	Managerial effectiveness									X		1
21	Meeting functional requirements	X										1
22	Meeting non-functional requirements	X										1
23	Net benefits						X					1
24	Operational quality			X								1
25	Organizational impact				X							1
26	Practitioners have a sense of achievement while working on a project								X			1
27	Practitioners have a sense of doing a good job								X			1
28	Product is used		X									1
29	Productivity improvement									X		1

No.	Success criteria	[P14]	[P7]	[P9]	[P10]	[P29]	[P15]	[P26]	[P13]	[P17]	[P12]	Times criteria
30	Project stakeholder satisfaction						X					1
31	Quality		X									1
32	Quality of Project management process						X					1
33	Requirements are accepted by the development team as realistic/achievable								X			1
34	Resources savings									X		1
35	Scope										X	1
36	Service Quality						X					1
37	System is used by end-users	X										1
38	System Use				X							1
39	Team is satisfied		X									1
40	The ability to meet project goals					X						1
41	The expected amount of work completed					X						1
42	The project is well planned								X			1
43	The quality of work completed					X						1
44	There is a project plan,								X			1
45	Time		X									1
46	Use / Intention to Use						X					1
47	Use level of satisfaction							X				1
48	Within budget						X					1
49	Within specifications						X					1
50	Within time						X					1

The list of criteria determined by the authors is shown in table 6, this list is extensive, although there is a similarity among them. As an example, about the budget: ‘Adherence to budget’, ‘Budget’, ‘Financial budget’, ‘Within Budget’; in other cases, the similarity is found reading the description of the criteria consigned by the authors, as an example, Pankratz and Basten [P14] list as criterion ‘Process Efficiency’ and defines it as ‘Ratio of objective achievement to expended effort (budget, particularly human resources)’, whereas Subiyakto et al. [P17] in simple form list as criterion ‘Resources savings’. Besides, based on the variable name and description indicated by the authors, a single variable description has been compiled. This information is showed in table 7.

Based on the identification of similar definitions, fourteen criteria were synthesized (see table 7). Each of these fourteen criteria has been related to one of the five categories established by Gollner and Baumane [P15]. Four criteria were found that were not part of the initial list of criteria: process efficiency, goals achievement, the team is satisfied, and business impact; these criteria were included in the list in their corresponding category. An additional note, in the ‘economic value’ category, Gollner and Baumane included the criterion 'net benefits'; however, the description corresponds to what other authors called 'individual impact' or 'impact on users.'.

Table 7. Project Success Criteria and Category (Synthesized Variables)

Times Category	Success Criteria Category	No.	Success Criteria	[P14]	[P7]	[P9]	[P10]	[P29]	[P15]	[P26]	[P13]	[P17]	[P12]	Times Criteria	Criteria Definition
19	Project management	1	Scope / Specifications	X	X			X	X				X	5	[P14] Conformance between specified functional and non-functional requirements and their actual realization. [P15] Within specifications is testing whether the predefined specifications were achieved for go-live, goals of project were reached, and scope of project was kept. [P12] The actual scope of an implementation with respect to the planned implementation.
		2	Process Efficiency	X		X		X				X		4	[P14] Ratio of objective achievement to expended effort (budget, particularly human resources). [P29] efficient task operations. [P17] Resource savings.
		3	Goals Achievement					X			X		X	3	[P29] The ability to meet project goals. [P13] Practitioners have a sense of achievement while working on a project. [P12] The existence and achievement of project goals.
		4	Quality of Project Management						X		X	X		3	[P13] The project is well planned. [P17] Managerial effectiveness.
		5	Project Stakeholder Satisfaction	X					X					2	[P14] The contractor organization's stakeholders are satisfied with the project. [P15] For Project Stakeholder Satisfaction, the narrower definition of the term stakeholder is applied, focusing on the influencers and decision-makers of business or technological change, adopting the stakeholder approach to management.
		6	Team is Satisfied		X						X			2	[P13] Requirements are accepted by the development team as realistic/achievable. Practitioners have a sense of doing a good job.
12	User Satisfaction	7	User / Customer Satisfaction	X	X	X	X		X			X	X	7	[P14] Customer organization's stakeholders are satisfied with the project. [P10] User satisfaction records the satisfaction level as reported by system users, including information, software, interface, overall satisfaction, ERP project satisfaction, etc. [P15] User Satisfaction describes the user's level of satisfaction when utilizing an ERP system. [P12] Users' level of satisfaction from the system introduced.
		8	Use / Intention to Use	X	X		X		X	X				5	[P14] The developed system is deployed at the customer organization and is used by end-users after project completion. [P10] Use of ERP system refers to the frequency at which an information system is used. Items like the rate of using ERP to assist in making decision, charge for ERP system use, and amount of connecting time are examined. [P15] The success dimension Use/Intention to Use represents the degree and manner in which an ERP system is utilized by its users.
10	Time & Budget	9	On Budget	X	X			X	X				X	5	[P14] Conformance between planned and actual development cost. [P15] Within the budget is controlling whether the project budget within predefined specifications is not exceeded, the budget was used effectively and evaluates expenses for extra requirements. [P12] Financial budget with regard to the planned budget.

Times Category	Success Criteria Category	No.	Success Criteria	[P14]	[P7]	[P9]	[P10]	[P29]	[P15]	[P26]	[P13]	[P17]	[P12]	Times Criteria	Criteria Definition
		10	On-Time	X	X			X	X				X	5	[P15] Within Time is checking whether main milestones and go-live were reached in time with predefined specifications. It also includes the time span of the ERP project. [P12] The actual duration with respect to the assumed duration;
6	System Quality	11	System Quality		X	X	X		X					4	[P10] System quality denotes system performance like data accuracy, database contents, data currency, system accuracy, responses, etc. [P15] System Quality measures the information processing system itself / The success dimension Service Quality represents the quality of the support that the users receive from the IT department like training and consulting. It also measures the goodness of hotline or helpdesk provided by IT support personnel.
		12	Information Quality				X		X					2	[P10] Information quality refers to the quality of the IS product, such as believability of output, timeliness of output, the usefulness of output, understandability of output, and relevance of output. [P15] Information Quality measures the information system output.
6	Economic Value	13	Business Impact				X			X		X		3	[P10] Organizational impact requires the evaluation of changes caused by the information system to the organization, such as a decrease in operating cost, savings in labor costs, and growth in profits. [P26] The business improvements the system has introduced.
		14	Impact on Users				X		X			X		3	[P10] Individual impact refers to measuring the impact of the information system on individual users, reflected by job performance, individual productivity, decision quality, information awareness, inventory etc. [P15] Net Benefits, which roughly consist of Individual Impact, describing the measure of the effect of information on the recipient or user.

4.2 RQ2: What are the critical factors for project success most referenced in IT project literature?

In IT literature, there is not a single agreement among authors about what are the critical success factors. Thirty-four authors worked on the analysis of the critical factors for project success. Regarding the meaning and use of the factor term, there is no similarity among authors. There are coincidences in the detail of lists that some authors called characteristics, other cues, factors, or items.

There were 263 factors collected from the researches of these authors. The most cited factors: top management support (five times), change management (three times), internal communication and user involvement. However, since the number of factors is so high; it is necessary to find a mechanism that allows us to synthesize and better understand this large number of factors.

In this study, factors were worked as variables that can be defined conceptually and operationalized to be measured. In each factor, an attribute (characteristic, quality, or property) was identified that applies to an object (person, activity, artifact, or event). The sequence of steps followed to obtain the synthesized factors is detailed below.

a) Identification of articles that analyze success factors and present conclusive studies about the incidence of these factors in project success: 34 articles studied success factors ([P14], [P2], [P19], [P7], [P10], [P29], [P27], [P34], [P30], [P38], [P1], [P16], [P5], [P6], [P20], [P8], [P21], [P26], [P28], [P11], [P35], [P31], [P13], [P37], [P22], [P3], [P17], [P18], [P4], [P12], [P26], [P32], [P23], [P24]) and 5 articles studied failure factors ([P25], [P33], [P27], [P38], [P22]).

b) Factors that correspond to papers that study a specific group of factors were discarded. For example, the analysis is concentrated in a single factor project related motivation [P14], only technical factors linked to quality product [P8], only factors linked to project management methodology [P21], only factors related to staff [P26], only factors related to people [P3]. In addition, paper [P29] that studies four factors as categories and does not analyze factors in detail was discarded.

c) Success factors that, in their definition, are found that correspond to failure factors were discarded. For example, 'Business Case, estimating and financial management' defined as 'Poor business case definition; project benefits are not clearly defined or properly estimated and poor financial management'; 'Requirement and scope management' defined as 'Failings as a direct result of inadequate requirements definition or poorly managed scope creep during the project life cycle' [P2].

d) Factors that, in fact, are criteria of success and not factors were discarded. For instance: 'Fulfilling business' and 'Implementation goal'.

e) 'Factors' that were not variables that can be measured were discarded. For example, 'Project environment' without a definition It is not clear which is the attribute to measure; 'Project management and control', 'Project planning', 'Project definition process', 'Risk analysis', 'interface management', 'IT infrastructure', they are activities or resources and not factors.

At this point, the number of factors that result was 187.

f) Each factor was discomposed in an attribute and an object, identifying the attribute that is measured on the object. For instance, the factor 'maturity of the organization' is discomposed as attribute 'maturity' and object 'organization; 'experienced participants' is discomposed as attribute 'experience' and object 'participant'.

g) Attributes and objects with the same meaning have been synthesized. For example, 'Use of planning' factor, whose description indicates effective use of planning, is synthesized with the 'effective planning' factor, leaving a single attribute 'Effective/use of'; in the case of factors 'a clear project goal', 'clear responsibilities', 'clarity of the project', a single attribute has been synthesized as 'clarity'; also factors that have this implicit attribute have been added to 'clarity' attribute.

The number of attributes resulted in thirty-seven, while the number of objects in thirty-three. A double-entry consolidated matrix (attribute vs. object) was created, and each cell shows the number of times that attribute associated with that object is found. The final matrix is shown in table 8.

The most referenced attributes: 'involvement', 'support', 'communication',' knowledge and technical expertise', 'commitment' and so on are shown in upper rows (from top to bottom); while in left columns (from left to right) the most referenced objects are shown: team members, users, top management, consultants, organization, internal members, participants or stakeholders, project manager and more.

Regarding the most cited attributes, 'Involvement' is defined as playing a significant role, incorporation of point of view, the influence, and participation in important decisions. 'Involvement' means active participation throughout the project. Whose 'involvement' is expected? From users: "User involvement means that the end-user of the project outcome should be consulted throughout the project" [P6], 'the incorporation of the user's viewpoint into project management" [P22], from top management: "Top management awareness regarding the project goals and complexity, labor required, existing limitations, required capital investment and project inevitability" [P12], "The use of a champion in a significant role is important to project success. Projects reporting a significant role of a champion were more successful than those without champions or where the champion did not play a significant role." [P28]; from the team and participants: "The project manager and members of the implementation team are strongly involved in the implementation duties" [P12], "Coworker influence means that the project manager does not make important decisions without consulting with the team" [P6].

Table 8. Project Success Factors Expressed as Attributes That Impact Objects

		Objects																															
		Team-members	Users	Top Management	Consultants	Organization	In-house/Internal/Intercompany	Participants or Stakeholders	Project Manager	Contractors/Suppliers/Providers	Techonology and IS	Project Organization	Planning	Project Management	Scope and Requirements	Changes and Deviations	Sponsor	Operational Processes	Tools e Infraestructure	Customers	Plan	Financial Resources	Agility Methodology	Implementation	IT area	Expectation Management	Crisis and Conflicts	Size and Complexity	Business case	Project Objectives	Schedule	Metrics	Software Selection	Control	Times
Attributes	Involvement	1	7	2				2									2			1					1									16
	Support		1	11	1																		1											14
	Communication	1	1				6	1		1										1	1								1						13
	Knowledge and Technical Expertise				5			1		1					1				1				1	1											11
	Commitment			2		1	1						2				2																	1	9
	Ability to Handle								1							3										1	2					1			8
	Effective / use of												5	2					1																8
	Capability	3	2		1																			1											7
	Training	1	4				1											1																	7
	Clarity / Definitions										1	2			1															1	1	1			7
	Managerial Skills								1							2									2	1									6
	Skills	3						1	1																										5
	Availability							1											1			3													5
	Adherence													1				2			1											1			5
	Alignment and suitability										1	1																	1	1	1				5
	Trust and Confidence				2				1	1																									4
	Experience					1		1			1							1																		4
	Maturity					3					1																								4
	Environment quality	2				2																													4
	Leadership								3																										3
	Professionalism and Integrity	1						1																1											3
	Competencies	2												1																					3
	Politics and norms	1				1		1																											3
	Culture					3																													3
	Capacity	1																	1				1											3
	Dedication Time	1							1						1																				3
	Agreement or consensus														2						1														3
	Structure and Responsibilities											3																							3
	Soft Skills				2																														2
	Emphaty				1					1																									2
	Responsiveness				1					1																									2
	Cooperation									1										1															2
	Empowerment	1										1																							2
	Quality									1													1												2
	Compatibility										2																								2
	Documentation and Methodology													2																					2
	Reliabiity									1	1																								2
Times		18	15	15	13	11	8	9	8	8	7	7	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1	187
		10%	8%	8%	7%	6%	4%	5%	4%	4%	4%	4%	4%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	100%
		the most referenced objects for success factor (pareto 80%)															the less referenced objects (20%)																		

'Support' defined as to assist to; to give approval, comfort, or encouragement to; be actively interested in and concerned for the success of. Whose 'support' is expected? from top management: "Support from management, managerial experience, Position of the Board of Directors in the corporate organizational chart" [P1], "Top management support means that the project sponsor is actively involved in the project." [P6], "Top management adherence to project execution goals, participation in project trends formation, readiness to allocate resources and authority necessary for project execution." [P18], "In the close-knit SME work environment, management leads by example. Encouraging employees positively towards the project is just as important as providing sufficient resources" [P27], "Top management support for the project, and the management members' involvement in implementation duties" [P12].

'Communication' defined in the dictionary as the imparting or exchanging of information by speaking, writing, or using some other medium. Communication between whom? Mainly Internal-In house, team members, users, stakeholders, and suppliers are also indicated. 'In house communications' [P18], 'user-customer-contractor dialogue' [P22], "Internal communication means the communication within the project team" [P6], "Triggering effective communication" [P10]. Communication of what? Plan "working routines should be standardized and communicated to relevant personnel" [P6], 'communicating the case' [P34].

'Team members' is the most referenced object. This object is also often referenced with the name of participants, or internal or in-house members. What are the attributes that the literature points out that the team should have? These attributes are quite diverse; Capabilities and skills: "The implementation team consists of various people having high qualifications and knowledge about the enterprise" [P12], "The own staff company having necessary skills, knowledge, and experience regarding implementation project" [P18], "Skill level of the team remaining on the project through test/transition" [P22], "Skilled team refers not only to competent personnel in general but requires that the team as a whole covers relevant knowledge perform all tasks in the project." [P6], 'Team Capability (in terms of Timeliness and Cost)' [P11], "Integrity" [P17], "Skills and competencies of project members" [P16]; Time-dedication: "The work time assured for the implementation team members (work time schedule)" [P12]; Empowerment: "The empowerment of the project team members to make decisions and their high position in the enterprise hierarchy" [P12]; Environment (quality): "Team Environment (in terms of Quality)" [P6].

The results can also be read following the intersection between attributes and objects. The most referenced factor with eleven times frequency is 'support of top management' composed by attribute 'support' and object 'top management'; then 'user's involvement' with seven times; followed by 'internal communication' (six times) and 'knowledge and technical expertise of the consultants' and 'effective of planning' (five times).

4.3 RQ3: Which are the categories in which the critical factors for IT project success have been grouped?

Therteen authors worked on categories of success factors, mostly taking previous studies as a reference. Paper from Stankovic et al. [P20] was not included because they used the categorization of Chow and Cao [P11]. Paper from Karlsen et al. [P31] was included even though it takes categories proposed before by Belassi and Tukel [15].

The list of 41 different categories found in the literature is shown in table 9. Each author grouped factors following different criteria. In some cases, criteria names are similar and, in other cases, are quite similar to a word that accompanies it, and that introduces some specificity to the category.

Curcio et al. [P1] classify in three categories, factors related to individuals, technology, and organization. Some particularities: the support of top management is included in the category of organizational factors, not in factors related to individuals. It does not include factors related to project management and is very extensive in terms of factors related to technology; this is because its study focuses on factors related to software quality as an element of success in a software development project.

Two authors propose a more atomized grouping that includes seven categories, each group with an extensive list of factors. Amid et al. [P25] based on a list of forty-seven factors study the categorization of thirty-five factors, while Sudhakar [P39] based on a review of the literature studies categories and proposes a model that relates these categories. Both include the categories: organization, technical, and project management; besides, the first author includes: human resources, processes, managerial and vendors, and consultants, while the second also considers: communication, environment, product, and team.

Pecherskaya et al. [P18] present a double categorization of factors, first grouping them into key participants and key activities, and at the same time, classifies them as hard or soft categories. He is the only author who proposes a second grouping. This study emphasizes the relevance of soft factors.

A peculiar grouping is presented by Saadé, Dong, and Wan [P5]; the proposed categories are different from all other authors: engagement traits, education, and experience. These three categories seem to correspond to the grouping of attributes that impact on the different objects that are referenced in the factors.

Samuel and Kumar [P19] propose three categories: user group, internal support, and external support. Internal support category includes top management and project team, while external support includes vendors and consultants. In general, these categories refer only to crucial project participants.

The most uncomplicated grouping is of two categories. Sheffield and Lemétaver [P7] present project factors and project environment factors. Project environment factors category includes factors related to the organization and top management, while the project factors category includes factors related to management, the team, and the nature of the project (size, complexity, etc.).

Chow and Cao [P11] propose grouping through five categories and conclude with four relevant categories: organizational, technical, process, and people. There is a coincidence with other authors in the first three with the same category name and not in the fourth that authors call people; although the name of the 'people' category does not coincide precisely with other authors, it is similar to 'human resources', 'individual factors', 'team', 'key project participants' or 'related to implementation participants'. It should be noted that in the 'process' category it brings together factors related to project management as well as factors related to the development methodology; 'technical' category includes factors related to the technical activities for product development; the project category that was dismissed included factors related to the nature of the project.

Salmeron and Herrero [P36] raise three categories: human resources, information & technology, and system interaction, and authors propose a model of the relationship between these categories. As a result, it suggests that technical elements are less critical than information and human factors. The relevance of the information in this study may be due to the nature of an EIS type project.

Authors Subiyakto et al. propose three categories: project contents that gather factors related to the nature of the project (size, complexity, etc.), people and actions that include mainly soft skills as well as organization and culture of the team, finally, institutional context category includes organization-related factors.

Karlsen et al. [P31] propose four categories: related to the project, related to the project manager and the team, related to the organization and factors related to external stakeholders; in this last category, factors as environment and resources and provision of an appropriate network are included.

Other authors who worked categories are Procaccino et al. [P13]. Authors list seven categories and focus on three categories: sponsor or management support and participation, customer or user support and participation, and requirements management. These three categories are identified as a critical chain of events for success in the model presented authors.

Given that the list of categories is vast and overlapped, it is necessary to synthesize in a parsimonious list. Based on the categorization made by Chow and Cao: organizational, technical, processes, and people, categories of each author were transferred in the related category of the original based category list, either by similarity or by being included within. In addition, the category named 'processes' was renamed by 'processes and project management', this in order to make explicit that factors related to project management processes are included in that category.

Taking the relation of objects worked in question 3, these have been grouped following the categories proposed by Chow and Cao, getting the summary that is shown in table 10.

People category is the most referenced group of critical success objects and factors, followed by processes and project management factors.

To group the attributes list, hard and soft categories proposed by Pecherskaya et al. were used. "Soft" ones are difficult to measure and tend to be nonmaterial, ambiguous, related to the areas of human psychology and organizational behavior. "Hard" ones are more easily measured and are usually associated with uniquely interpreted phenomena [P18]. Table 11 shows the list grouped by hard and soft categories.

Table 9. Project Success Factors Categories in IT Literature

Categories	[P13]	[P36]	[P31]	[P12]	[P11]	[P25]	[P39]	[P7]	[P19]	[P18]	[P5]	[P17]	[P1]	Times
Organizational			X		X	X	X						X	5
Technical					X	X	X							3
Human Resources		X				X								2
Processes					X	X								2
Project			X					X						2
Project management						X	X							2
Communication							X							1
Customer/users	X													1
Education											X			1
Engagement traits											X			1
Environmental							X							1
Experience											X			1
External stakeholders			X											1
External support									X					1
Hard										X				1
Individual Factors													X	1
Information & Technology		X												1
Institutional context												X		1
Internal support									X					1
Key business activities										X				1
Key project participants										X				1
Managerial						X								1
People					X									1
People and actions												X		1
Product							X							1
Project contents												X		1
Project environment								X						1
Project manager and team			X											1
Related to implementation participants				X										1
Related to information systems				X										1
Related to the project definition and organization				X										1
Related to the project status				X										1
Related to top management involvement				X										1
Requirements management	X													1
Soft										X				1
Sponsor/management	X													1
System Interaction		X												1
Team							X							1
Technological													X	1
User group									X					1
Vendors and consultants						X								1

Table 10. Project Success Factors Categories and Objects

People									Organizational				Technical			Processes and Project Management																		Times
[P13], [P36], [P31], [P12], [P11], [P25], [P39], [P19], [P18], [P17], [P1]									[P31], [P12], [P11], [P25], [P39], [P7], [P17], [P1]				[P36], [P12], [P11], [P25], [P39], [P1]			[P13], [P12], [P11], [P25], [P39],[P1]																	
Team-members	In-house/Internal/Intercompany	IT area	Participants or Stakeholders	Project Manager	Users	Customers	Consultants	Contractors/Suppliers/Providers	Top Management	Sponsor	Organization	Size and Complexity	Agility Methodology	Tools e Infraestructure	Techonology and IS	Plan	Business case	Financial Resources	Project Objectives	Operational Processes	Scope and Requirements	Schedule	Metrics	Project Organization	Planning	Software Selection	Control	Implementation	Expectation Management	Project Management	Crisis and Conflicts	Changes and Deviations		
Objects																																	
84									32				14			57																	187

Table 11. Project Success Factors Categories and Attributes

			Times	
Soft	Involvement	**Attributes**	16	116
	Support		14	
	Communication		13	
	Commitment		9	
	Ability to handle		8	
	Effective / use of		8	
	Managerial skills		6	
	Trust and confidence		4	
	Experience		4	
	Environment quality		4	
	Leadership		3	
	Professionalism and integrity		3	
	Culture		3	
	Agreement or consensus		3	
	Soft skills		2	
	Empathy		2	
	Responsiveness		2	
	Cooperation		2	
	Empowerment		2	
	Skills		5	
	Competencies		3	
Hard	Knowledge and technical expertise		11	71
	Capability		7	
	Training		7	
	Clarity / Definitions		7	
	Availability		5	

		Times	
	Adherence	5	
	Alignment and suitability	5	
	Maturity	4	
	Politics and norms	3	
	Capacity	3	
	Dedication Time	3	
	Structure and responsibilities	3	
	Quality	2	
	Compatibility	2	
	Documentation and methodology	2	
	Reliability	2	
		187	187

Attributes related to the areas of human psychology and organizational behavior are the most referenced by the literature.

5. Discussion

Regarding question RQ1, the results reaffirm what is indicated by the literature regarding the lack of a consensual definition on the concept of project success. It is difficult to make a definition of project success, so the higher number of authors recourse to a list of criteria of success with which they try to explain the project success concept.

The criteria list that defines the success of a project is much broader than the traditional list: scope, time, and cost. In the definition of success, the authors include variables related to quality, functionality and product performance; they also include variables related to the satisfaction of the stakeholders, mainly user satisfaction; likewise, they include a broad extent criterion related to the benefit and impact produced by the project to the organization, mainly economic benefit.

It is to notice that, in the definition of project success through criteria, the list of criteria mentioned is even broader than the list of criteria that have been worked as variables part of a study. This difference may be because some criteria are difficult to measure; there are objective variables that are easier to quantify respect to other subjective variables such as satisfaction. In another case, the transcendence of the project is more challenging to measure with respect to the criteria that can be measured immediately after finishing a project; this is the case of all variables related to project impact and benefits.

No two authors have coincided in the same list of success criteria. This variety of definitions and criteria reinforces the idea that the qualification of a successful project by each stakeholder depends on perception. Stakeholders have a different perception of the achievement, of the objectives, of their interest; and this is the reason why various studies have been carried out of the success linked to perception from the point of view of each stakeholder, linked to the cultural perspective, linked to the stages of the project, etc. The grouping of criteria of success through five categories that Gollner [P15] makes is a quite complete categorization since the full and varied list of criteria of all the authors easily fit into the five groups: Project management, Time & budget, user satisfaction, system quality, and economic value. This grouping goes well with the grouping made by other authors who distinguish process management success and product success. In this case, IT project management author includes Project management and Time & Budget as part of Project management success, user satisfaction, and economic value as part of the product success, and finally, the system quality group as part of project and product success. Figure 3 shows a summary of the criteria and their categorization.

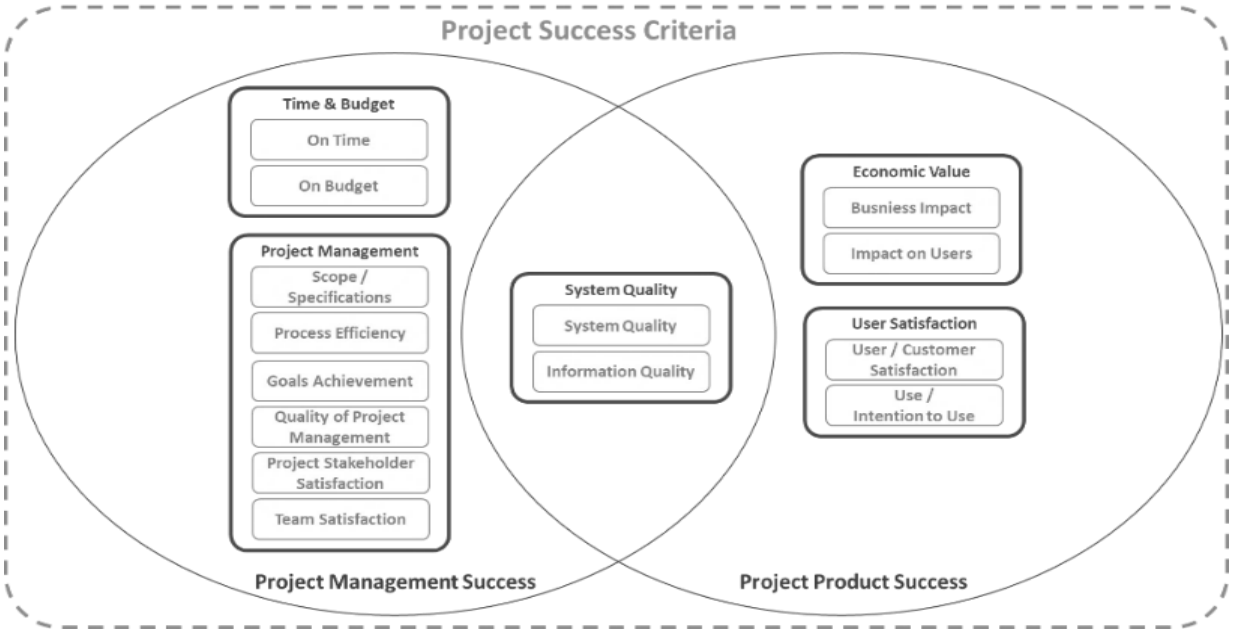

Fig. 3. Project Success Criteria. Variables and Categories.

This synthesis of IT project success criteria can be used to construct a scale of measurement of success specific to information technology projects.

As seen in the theoretical foundation, project success is a multi-dimensional concept depending on criteria, stakeholder perception, the context, and the moment the project is found.

This measurement scale could be developed considering as context the four bases to analyze projects proposed by Shenhar Novelty, Technology, Complexity and Pace (NTCP), since these four elements fit the described characteristics of IT projects, which are often innovative, highly complex and generally urgent. This aligned with the contingency theory that suggests considering contextual factors.

A measurement scale as an instrument will allow the project manager or project management office to more accurately assess the success or relative failure of their projects.

The significant number of factors existing in the literature and the little coincidence in some of them, has led to continuing searching for new ways to understand the problem. The most referenced factors were the support of top management, user involvement, and internal communication. These critical factors are quite similar to the factors identified by the widely cited authors Pinto and Slevin [68]; they include top management support, client consultation, and communication.

About questions RQ2 and RQ3, factors are numerous and overlapped. To solve this concern, this paper synthesized these factors through the decomposition of variables into attributes and objects to find which are the most relevant objects and which are the most referenced attributes to achieve success.

As a result of this classification (see tables 10 and 11), a crossed summary is shown in table 12. The most referenced factors are the soft attributes of people. This finding is not new, Belout [31] already in 1998 said that projects should not be seen only as technical systems but also as behavioral systems highlighting the importance of human resources factors. People's aspects have the most substantial impact on success or failure result.

The soft attributes (behavioral) are seen as general in the participants and the organization (e.g., skills of team members, user's involvement), as well as applied to specific management processes (e.g., the ability to manage change and

deviations, commitment to planning). The importance of the study of human behavior in IT projects for the achievement of success was already expressed in some researches; For example, in one study, 19 behaviors are grouped from 127 initially collected behaviors [69], other studies point out the relevance of the behavior and soft skills of the project manager [70, 71]. The identification of human factors as critical factors for the success of information technology projects is aligned with the characteristics of the technology projects that were described in the background.

In relation to complexity as the main characteristic of IT projects, it is often created by the interaction of people, organizations, and the environment. IT projects involve numerous iterations and continuous interaction, and their work is highly interdependent. It is this strong interaction of people, which implies the need for excellent people management, leadership, gain trust between them, excellent communication, involvement, commitment, and participation.

The uncertainty generated because of a poorly defined and lack of constraints. Due to the immateriality of the software, the software is effectively invisible, and there is a visualization problem source of many potential IT project failures. The abstract nature of the projects leads to different perceptions of each stakeholder, and these make understanding and communication difficult. Uncertainty is also generated because many IT systems seek to undertake or increase tasks previously performed by people. Again, given this characteristic, it is necessary to achieve excellent communication, trust, and involvement of the team with the needs of the client to understand the business and the processes in question.

The high degree of novelty of IT projects, the rapid pace of technological progress, and the urgency with which technology projects are worked, because generally market pressure demands delivery in the shortest time, leads to requiring an additional commitment of the team, cooperation, and support.

Table 12. Grouping of Objects and Attributes.

		People	Organizational	Technical	Process and Project Management	
		Objects				
Soft	Attributes	57	28	3	28	116
Hard		27	4	11	29	71
		84	32	14	57	187

An unexpected result is a low reference to technical factors. This could be since, in some instances, the interviews are directed to the project managers and sponsors, who may have a bias towards the elements closest to them.

6. Conclusions and future work

This paper presents a systematic literature review of IT Project studies on success factors and analyzes 39 papers studying success definition, success criteria, success factors, and success factors categories.

There is no single definition of project success. Authors define project success based on criteria related to the project management, product quality, stakeholder's satisfaction, and benefits of the project; the business impact criteria have been less studied; this may be due to the greater difficulty of measuring this variable.

While the criteria related to management can be similar in all types of projects, in the IT literature; the criteria related to the product have particular relevance: the quality of the system and the quality of the information that the system generates, the satisfaction of the user and the intention of using the system; as well as the impact that the product brings

to the organization and users, this aligned to the majority of IT projects involve software and are undertaken to deliver some kind of business or process change.

The IT project success literature shows no convergence in terms of the factors and their definitions, for example, participants or team members are used indistinctly; likewise, it shows overlap in its scope, for example, skills or soft skills or competencies.

In the most traditional list, the factors that receive the most mentions are top management support, user involvement, internal communication, knowledge and technical expertise of the consultants, and effective planning.

In a new way of view this list, the analysis of factors as variables composed of attributes that apply on objects, the most mentioned attributes are involvement, support, communication, knowledge, and technical expertise, and commitment. The most mentioned objects are the team members, users, top management, consultants, organization, participants, Project manager, and providers. This proposal of a structure (attributes vs. objects) to synthesize the information of factors constitutes a contribution of this investigation; previous works mainly present the factors as lists.

After grouping these factors, soft attributes take particular relevance, since they apply to people, organizations, and to project management processes. Soft skills or people skills are the most important critical factor for IT projects. The characteristics of IT projects lead to the need to manage human resources as a critical factor in achieving success in information technology projects. This research contributes to reinforcing the need to develop soft skills in technological project teams.

As future research topics, it is suggested work in studying a model for IT project success and explain how soft skills can influence in most essential objects to achieve desired project success. Similar way, it is suggested work in studying a model to explain which and how each soft skill can influence in each IT project characteristic. This will allow a better selection of the work team, involving professionals with skills better aligned to the nature and context of the project.

Although the search for articles was intended to cover all types of technology projects, the most significant number of articles were indeed found related to development projects or information systems implementation. This is a limitation of this study since very little or no literature was found on certain types of projects.

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Appendix A. Systematic Review Selected Papers

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Appendix B. Quality of studies

	1 Is the paper based on empirical research?	2 Is there a clear statement of the aims of the research?	3 Is there an adequate basis for the hypotheses?	4 Was the research design appropriate to address the aims of the research?	5 Was the data collection appropriate to the aims of the research?	6 Was the data analysis sufficiently rigorous?	7 Is there a clear statement of findings?	8 Is the study of value for research or practice?	Total Score
[P1]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P2]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P3]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P4]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P5]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P6]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P7]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P8]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P9]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P10]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P11]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P12]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P13]	Y	Y	Y	Y	Y	Y	Y	Y	8.0
[P14]	Y	Y	Y	Y	P	Y	Y	Y	7.5
[P15]	Y	Y	Y	Y	Y	P	Y	Y	7.5
[P16]	Y	Y	Y	Y	Y	P	Y	Y	7.5
[P17]	Y	Y	Y	Y	P	Y	Y	Y	7.5
[P18]	Y	Y	Y	Y	Y	P	Y	Y	7.5
[P19]	Y	Y	P	Y	Y	Y	Y	Y	7.5
[P20]	Y	Y	Y	Y	P	Y	Y	Y	7.5
[P21]	Y	Y	Y	Y	P	Y	Y	Y	7.5
[P22]	Y	Y	P	Y	Y	Y	Y	Y	7.5
[P23]	Y	Y	Y	Y	Y	Y	Y	Y	7.0
[P24]	Y	Y	N	Y	Y	Y	Y	Y	7.0
[P25]	Y	Y	N	Y	Y	Y	Y	Y	7.0
[P26]	Y	Y	P	Y	P	Y	Y	Y	7.0
[P27]	Y	Y	Y	N	Y	Y	Y	Y	7.0
[P28]	Y	Y	Y	Y	P	P	Y	Y	7.0
[P29]	Y	Y	N	Y	Y	P	Y	Y	6.5
[P30]	Y	P	P	P	Y	Y	Y	Y	6.5
[P31]	Y	Y	N	Y	Y	P	Y	Y	6.5
[P32]	Y	Y	N	Y	Y	Y	P	Y	6.0
[P33]	Y	Y	N	Y	P	P	Y	Y	6.0
[P34]	P	Y	P	Y	P	P	Y	Y	6.0
[P35]	Y	Y	N	Y	Y	Y	N	Y	6.0
[P36]	Y	Y	N	Y	P	Y	Y	P	6.0
[P37]	Y	Y	P	P	P	P	Y	Y	6.0
[P38]	Y	Y	N	P	P	P	Y	Y	5.5
[P39]	Y	Y	N	Y	N	N	Y	Y	5.0

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Carmen Iriarte is a Ph.D. Candidate at Universidad Nacional Mayor de San Marcos. She received his MBA from Universidad del Pacífico, Perú, and her bachelor in system engineering from National Engineering University, Perú. She had managed technology projects and areas in banking, insurance, and health organizations for more than twenty years. Her current research interests include soft skills in technology professionals.

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at www.sciencesphere.org/ijispm

M. Bach, K. Dumičić, B. Žmuk, T. Ćurlin, J. Zoroja, "Data mining approach to internal fraud in a project-based organization", *International Journal of Information Systems and Project Management*, vol. 8, no. 2, pp. 81-101, 2020.

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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Data mining approach to internal fraud in a project-based organization

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Abstract:
Data mining is an efficient methodology for uncovering and extracting information from large databases, which is widely used in different areas, e.g., customer relation management, financial fraud detection, healthcare management, and manufacturing. Data mining has been successfully used in various fraud detection and prevention areas, such as credit card fraud, taxation fraud, and fund transfer fraud. However, there are insufficient researches about the usage of data mining for fraud related to internal control. In order to increase awareness of data mining usefulness in internal control, we developed a case study in a project-based organization. We analyze the dataset about working-hour claims for projects, using two data mining techniques: chi-square automatic interaction detection (CHAID) decision tree and link analysis, in order to describe characteristics of fraudulent working-hour claims and to develop a model for automatic detection of potentially fraudulent ones. Results indicate that the following characteristics of the suspected working-hours claim were the most significant: sector of the customer, origin and level of expertise of the consultant, and cost of the consulting services. Our research contributes to the area of internal control supported by data mining, with the goal to prevent fraudulent working-hour claims in project-based organizations.

Keywords:
project-based organization; internal control; fraud; data mining; CHAID; association and link analysis.

DOI: 10.12821/ijispm080204

Manuscript received: 8 April 2019
Manuscript accepted: 7 December 2019

1. Introduction

Internal fraud has become one of the crucial and increasingly serious problems in numerous organizations. Internal control encompasses various policies and procedures designed for detecting and preventing fraud conducted by the organization's employees or external hires, which have to be constantly updated and monitored [1], in order to efficiently support the organization in its risk management activities. Internal fraud control is widely used for the purpose of forecasting, detecting and preventing possible fraudulent behaviors conducted by organizations' employees [2]. However, numerous organizations still have inefficient internal control systems [3].

Data mining techniques are widely used for external fraud detection and prevention. Literature review regarding data mining methods for the detection of financial fraud revealed that data mining techniques have been mostly used for detecting insurance fraud, corporate fraud, and credit card fraud [4]. Studies about internal control fraud are mostly focused on financial organizations and accounting [5], [6]. One of the examples of utilization of data mining for combating internal fraud investigates the utilization of data mining methods for detecting fraud by employees in a financial organization [7]. Project-based organizations are especially prone to internal fraud since due to the lower level of control that is the result of the flatter organizational structure [8], and in some cases a poor management practices [9] or complex governance procedures [10]. However, research about fraud detection and prevention in project-based organizations are scarce [11], [12].

In order to shed some light on the usefulness of the data mining approach for the detection of internal fraud in project-based organizations, we develop a case study, based on the dataset from one project-based organization. The dataset contains the characteristics of the working-hour claims (client, expert, job characteristics) in one project-based organization, which is analyzed by chi-square automatic interaction detection (CHAID) decision tree and link analysis. Using these two methods, we develop data mining models that discover the client, expert and job characteristics that are significant predictors of fraudulent working-hour claims. The contributions of this paper are two-fold. First, we contribute to the area of internal fraud detection and prevention in project-based organizations, while most of the previous research has been oriented towards external fraud prevention. Second, we provide practical contributions, since our research results in the form of decision tree and association rules could enable organizations for developing their own solutions for automatic internal fraud-detection (e.g., using SQL code).

The paper is organized into five sections. After the introduction, we present the literature review, with the goal of internal control, data mining and fraud prevention. In the methodology section, we overview the characteristics of the dataset, as well as the used methods (link analysis and CHAID decision tree). In the fourth section, we present research results, with the extensive elaboration of the rules extracted from the decision trees and link analysis. The last section concludes the paper with an overview of research, practical contributions, paper limitations and future research directions.

2. Literature review

2.1 Internal controls and fraud

Fraud represents a severe problem in companies; whether committed outside or inside an organization. Many organizations from various industries such as credit transactions; telecom, insurance, and management are affected by fraudulent activities [13]. Fraudsters could even be financial or other institutions themselves, involved in money laundering or financial statement frauds. A pilot survey for measurin financial fraud in the USA found out that the fraudster most commonly executed frauds online (30%) with the credit card payment (32%) [14]. Consider that those numbers are not even accurate because fraud is often not reported because of the possible negative impact on the organizations' image. On the other side, fraud committed inside the organization is also common, generating a high loss, both in terms of money and loose of trust [15].

The purpose of internal control is to detect and prevent fraudulent behavior, and thus support the company's performance and achieve established goals. Opportunities for fraud occur in organizations, which have weak

compliance with internal controls [16]. Internal fraud is a growing problem in many companies and organizations, which indicates that it is necessary to investigate this problem further and deeper in order to get better internal control systems [17]. On the other hand, many organizations lack the strategy to develop and maintain an efficient internal control system. Insufficient and flouted internal controls give opportunities for personnel to commit unethical practices and fraud in an organization [3]. There are numerous recommendations related to increasing the efficiency of internal control systems, such as the usage of global positioning tracking units (GPS), monitoring of unutilized purchase orders and pre-approval of overtime work. However, progress is slow due to difficult access to data from previous cases, so it is hard for problem solvers to develop new methods and solutions [2].

2.2 Data mining

The main task for data mining is to extract the most significant patterns from databases in various organizations and institutions. Data mining is acting as a tool that delivers data for further investigation, interpretation, and understanding [18]. Kantrarzic et al. [19] define data mining as "iterative process within which progress is defined by discovery, either through automatic or manual methods", acknowledging that the exploratory analysis scenario, without predetermined notion on the possible results, is the domain where data mining is the most useful. There are three fundamental goals for data mining processes: description, prediction, and prescription. Data describing human-interpretable patterns are focused on the description, while the usage of variables in the database to predict unfamiliar or forthcoming values of other variables is primarily focused on prediction [20]. The main objective of prescription is providing the best solution to the actual problem. All three goals are possible to accomplish by data mining techniques, such as classification, prediction, outlier detection, optimization, and visualization.

A number of challenges occur when considering the development and implementation of data mining [21], who stress the following: performance time, management support, selection and execution of algorithms. Although the first concern is usually the performance time (the importance of real-time action, online vs. offline methods), another big challenge that emerges is the cost management related to employee costs, consultants, software and hardware. The second concern would be the choice of the data mining technique. Data mining techniques have their own challenges in the development process: not all the data needed to perform tests is available to the public, and there is also a big lack of well-researched methods, algorithms, and techniques. The chosen method will depend on the structure of the data and the type of results that are wanted from the analysis. Finally, the main concern is focused on the actual usage of data mining results in the decision-making, it is rarely technical and usually depends on management willingness to support the application of data mining.

2.3 Data mining for internal fraud detection

In the last decade, significant progress took place, and automated fraud detection systems based on data mining models have gained enormous popularity, especially within financial institutions [4]. In terms of data mining, fraud analysis is a process, which consists of a sequence of actions, or a group of characteristics that could be used for predicting or discovering potential or explicit threats of fraudulent activities. Data mining has remarkable results in diverse fields related to security and fraud, financial crime detection (money laundering, suspicious credit card transactions and financial reporting fraud), intrusion and spam detection [22]. However, data mining implementation in the area of internal fraud risk reduction is mostly focused on the analysis of financial statements [23], [24], [25]. Kranacher et al. [22] distinguish three categories of internal fraud on which most studies are focused: financial statement fraud, transaction fraud, and abuse of position. Data mining techniques can decrease the probability of internal fraud. Various methods have been used for developing data mining models for internal fraud prevention and detection, such as multivariate latent clustering, neural networks, logistic models and decision trees [26], [27].

Data mining has become one of the most important paradigms of advanced intelligent business analytics and decision support tools for internal fraud prevention [28], [29], [23]. Many organizations acknowledge data mining as one of the main technologies relevant to internal fraud prevention nowadays and in the future. The Institute of Internal Auditors – Australia [30] recommends the usage of data mining for auditing process, and The Chartered Global Management

Accountant has reported that data mining lies within the top ten focus priorities fundamental for the data-driven era of business and was ranked as relevant by more than half corporate leaders [31].

3. Methodology

3.1 Data

In order to inspect internal fraud, we have conducted a case study analysis on the data available from one large company. This company is organized using a project-based organizational structure, which means that projects present the key organizational activity [32], [33]. The company has more than 300 employees and implements and develops business-related software applications. Each month, employees working on a project-basis provide a report on their work including the number of hours, the characteristics of clients, the complexity of their work, and the amount claimed for an hour and in total. Based on this information, the working-hours claim is filled each month. The company has already developed its own methods for detecting suspicious working-hour claims, but those are focused on the detection of already committed fraudulent activities, while more research is needed in order to identify the characteristics of fraudulent claims in order to detect potential new ones. Therefore, the goal of this research is to determine the characteristics of the suspected working-hour claims, which are the candidates for in-depth fraud analysis, and to develop a model for preventing fraudulent behavior.

The company defines the suspect claims in the following manner. A working-hours claim is suspect if at least one of the following criteria has been met: (i) if a consultant is late in submitting the working-hours claim more than seven days from the day when the project is finished, and (ii) if a consultant cancels already claimed working-hours. In the case when at least one of the abovementioned criteria is fulfilled, the working-hours claim is considered as a suspect for fraud. The management of the company believed that it would be beneficial to identify the characteristics of the potential fraud (suspect) working-hour claims before the consultant is already late in submitting the claim.

Dataset consists of 1,194 working-hours claims, which comprise 5% of the total working-hours claims in the company in the observed year. According to Table 1, 294 working-hours claims, or 24.62%, were suspect for fraud whereas 900 working-hours claims, or 75.38%, were non-suspect for fraud. The variable Suspect defines these two categories of working-hours claims (if the claim is suspected it has value 1, otherwise it is equal to 0).

Table 1. Suspect and non-suspect working-hour claims in the sample

Variable Suspect	Count	Percent
Suspect (value 1)	294	24.62
Non-suspect (value 0)	900	75.38
Total	1,194	100.00

Source: Authors' work, based on the internal data source.

The independent variables in the working-hour claims are used for developing data mining models:

- Type of customer – variable Customer;
- Type of consultant – variable Consultant;
- The month when the working-hours were claimed – variable Month;
- The hourly-rate – variable UnitPriceCoded;
- The consultant's level of expertise – variable ExpertLevel;
- The number of hours claimed – variable NoHoursCoded;
- The total amount claimed – variable TotalAmountCoded.

The following analysis will present the distribution of the independent variables according to the fraudulent working-hour claims.

The distribution of the variable Customer is presented in Table 2. Customers ordering the work on the project (development and/or implementation of software applications) are divided into three categories: governmental institutions, internal projects, and private enterprises. Internal projects are suspected in a 50.68% case. The conducted chi-square test confirmed, at the significance level of 1%, that there is at least one category of customers whose structure according to the variable Suspect is different from the others (chi-square=77.435, df=2, p-value<0.001).

Table 2. Types of the customer – variable Customer

Customer origin	**Suspect**	**Not suspect**	Chi-square	P-value
Govern	4.76%	95.24%	77.435	<0.001
Internal	50.68%	49.32%		
Private	22.80%	77.20%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

The variable Consultant describes the country of origin of experts, who have been claiming working-hours, since in some cases domestic consultants (from Croatia) and in some cases, foreign consultants are hired (Table 3). In cases when domestic consultants are observed, 23.46% of their working-hour claims were suspected, while foreign consultants were in 41.56% cases in the suspected working-hours claim category. The chi-square test has shown that, at the significance level of 1%, domestic and foreign employees have a statistically significantly different structure according to suspected and non-suspected working-hours claims (chi-square=12.719, df=1, p-value<0.001).

Table 3. Types of consultant – variable Consultant

Consultant origin	**Suspect**	**Not suspect**	**Chi-square**	**P-value**
Domestic	23.46%	76.54%	12.719	<0.001
Foreign	41.56%	58.44%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

The variable Month represents the month in which a consultancy service was provided (Table 4). For the purpose of the analysis, months are coded as discrete values ranging from M1 to M12. The highest share of suspected working-hours claims can be found in months M1 (65.77%) and M12 (30.59%), which refer to January and December. It is highly probable that this large percentage of suspect claims are related to the beginning and the end of the fiscal year. On the other hand, the highest share of non-suspected working-hours claims is in months M10 (88.42%) and M4 (86.40%). According to the conducted chi-square test, those shares seem to be statistically significantly different, at the significance level of 1%, in different months (chi-square=134.670, df=11, p-value<0.001).

Table 4. The month when the working-hours were claimed – variable Month

The month of the claim	Suspect	Not suspect	Chi-square	P-value
M1	65.77%	34.23%	134.670	<0.001
M2	28.13%	71.88%		
M3	17.31%	82.69%		
M4	13.60%	86.40%		
M5	16.81%	83.19%		
M6	20.39%	79.61%		
M7	14.29%	85.71%		
M8	28.09%	71.91%		
M9	25.93%	74.07%		
M10	11.58%	88.42%		
M11	19.28%	80.72%		
M12	30.59%	69.41%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

The variable UnitPriceCoded was used to take into account the cost of consultants (Table 5). In the analysis, this cost is expressed per hour. The minimum cost per hour is 19.9 EUR, and the highest is 173.9 EUR per hour. Because there are many different values, it has been decided that four groups of costs will be formed and that the unit price will be coded in four categories (1-50 EUR per hour, 51-100 EUR per hour, 101-150 EUR per hour, and 151-200 EUR per hour). The largest share of suspected working-hours claims was found in the category of the cost of 151-200 EUR (30.00%) whereas the largest share of non-suspected working-hours claims was found in the category of the cost of 1-51 EUR (89.19%). The chi-square test has shown that, at the significance level of 5%, the hypothesis of equal shares of suspected working-hours claims, or non-suspected working-hours claims, at all the four observed cost levels cannot be rejected (chi-square=6.278, df=3, p-value=0.099).

Table 5. The hourly-rate – variable UnitPriceCoded

The hourly rate	Suspect	Not suspect	Chi-square	P-value
1-50 EUR per hour	10.81%	89.19%	6.278	0.099
51-100 EUR per hour	25.59%	74.41%		
101-150 EUR per hour	18.75%	81.25%		
151-200 EUR per hour	30.00%	70.00%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

The variable Expert Level (Table 6) reflects the five expert levels coded from L4 to L8, which refer to the experience and relevant knowledge of consultants claiming working-hours (L4 is the lowest level of expertise, while L8 is the top

level of expertise). The highest share of suspected working-hours claims is present at the expert level L5 (77.78%) whereas the highest share of non-suspected working-hours claims is present at the expert level L4 (89.19%). The chi-square test confirmed that, at the significance level of 1%, there is at least one expert level at which shares of suspected working-hours claims or non-suspected working-hours claims are statistically significantly different than at other expert levels (chi-square=33.147, df=4, p-value<0.001).

Table 6. The consultant's level of expertise – variable ExpertLevel

Consultant	Suspect	Not suspect	Chi-square	P-value
L6	24.69%	75.31%	33.147	<0.001
L5	77.78%	22.22%		
L8	30.00%	70.00%		
L4	10.81%	89.19%		
L7	18.75%	81.25%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

Table 7 outlines the number of weekly working hours of employees or consultants (the variable NoHoursCoded). There is a quite large number of discrete values of weekly working hours. Consequently, they are classified into eight groups: 1-5; 6-10; 11-15; 16-20; 21-25; 25-30; 31-35; and 36-55. Due to some administrative problems, an additional category was introduced to incorporate negative weekly working-hours, which appeared due to some corrections conducted by consultants themselves. It is a company policy that, in the case of negative weekly working-hours, these working-hour claims are treated as suspected. The Chi-square test has shown that, at the significance level of 1%, there is at least one weekly working-hours category at which the share of suspected working-hours claims is statistically significantly different than at other weekly working-hours categories (chi-square=53.859, df=8, p-value<0.001).

Table 7. The number of hours claimed – variable NoHoursCoded

The number of hours	Suspect	Not suspect	Chi-square	P-value
Negative hours	100.00%	0.00%	53.859	<0.001
1-5 hours	22.63%	77.37%		
6-10 hours	26.06%	73.94%		
11-15 hours	26.90%	73.10%		
16-20 hours	23.39%	76.61%		
21-25 hours	17.65%	82.35%		
25-30 hours	9.68%	90.32%		
31-35 hours	23.08%	76.92%		
36-55 hours	21.05%	78.95%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

The costs of consultants' working-hours are observed by the variable TotalAmountCoded (Table 8), and those costs have been categorized into 19 cost categories. A negative amount is claimed for the working-hour claims with negative hours, which was elaborated for the variable NoHoursCoded (Table 7). The conducted chi-square test has shown that, at the significance level of 1%, there is at least one total cost per consultant category at which the share of suspected working-hours claims is statistically significantly different (chi-square=80.068, df=18, p-value<0.001).

Table 8. The total amount claimed – variable TotalAmountCoded.

The total amount claimed	Suspect	Not suspect	Chi-square	P-value
1-100 EUR	25.30%	74.70%	80.068	<0.001
101-200 EUR	16.94%	83.06%		
201-300 EUR	24.56%	75.44%		
301-400 EUR	24.17%	75.83%		
401-500 EUR	24.21%	75.79%		
501-600 EUR	24.51%	75.49%		
601-700 EUR	31.52%	68.48%		
701-800 EUR	16.67%	83.33%		
801-900 EUR	13.33%	86.67%		
901-1000 EUR	42.42%	57.58%		
1001-1100 EUR	35.19%	64.81%		
1101-1300 EUR	27.87%	72.13%		
1301-1500 EUR	29.33%	70.67%		
1501-1600 EUR	5.56%	94.44%		
1601-1700 EUR	15.38%	84.62%		
1701-2000 EUR	22.22%	77.78%		
2001-3000 EUR	18.97%	81.03%		
3001-4000 EUR	13.79%	86.21%		
Negative	100.00%	0.00%		
Totals	24.62%	75.38%		

Source: Authors' work, based on the internal data source.

3.2 CHAID decision tree

In order to provide an understanding of the interrelation between working hours claim fraud and various characteristics, such as characteristics of customers, consultants, expert knowledge and others, a decision tree is developed using the CHAID algorithm. As the name reveals, the CHAID decision tree is based on the chi-square test, which is used to select the best split at each step. In order to construct a decision tree, the role of the dependent variable was given to the variable Suspect. All other observed variables have taken the role of independent variables (Customer; Consultant; Month; UnitPriceCoded; ExpertLevel; NoHoursCoded; TotalAmountCoded). In order to get a clear and easily understandable classification tree, it has been decided that the classification tree depth should go up to the third level, which is indicated by Bertsimas et al. (2017) [34], as the optimal depth of the tree. Furthermore, it has been defined that the main or parent node should have at least 100 cases whereas the following or child nodes should have at least 50

cases, which comprise approximately 8% and 4% respectively of the total sample (1,194 cases). The decision tree is developed using SPSS ver. 23.

3.3 Link analysis

Link analysis is a data analysis technique, which can be used for identification and evaluation of relationships between items that occur together, and which can be represented as "nodes." Different objects like enterprises, employees, customers, transactions, and similar can be referred to as nodes. Link analysis is used for the detection of potentially suspect working-hours claims based on characteristics of clients, consultants, and projects. By using link analysis, the association rules are extracted in order to detect significant relationships between suspect working-hours claims and various characteristics of customers, consultants, and projects. Association rules can be described as:

$$\text{If A=1 and B=1 then C=1 with probability p} \tag{1}$$

where A, B, and C are binary variables, p is a conditional probability defined as $p = p(C = 1|A = 1, B = 1)$. Furthermore, the association rule can be simply written as $A \Rightarrow B$, where A is the body of the rule and B is the head of the association rule [35].

In the analysis, all eight variables are included: Suspect; Customer; Consultant; Month; UnitPriceCoded; ExpertLevel; NoHoursCoded; TotalAmountCoded. Because there is no defined and strict order between variables and items, it has been decided that the non-sequential association analysis approach will be applied [36]. Link analysis has been conducted using Statistica Data Miner software ver. 13.5.

The minimum support value, which shows how frequently an itemset appears in the dataset, has been set to value 0.2 whereas the maximum value was set to 1.0. Support is calculated as:

$$\text{Support } (A \Rightarrow B) = p(A \cup B) \tag{2}$$

Items with support value lower than the minimum value will be excluded from the analysis. Similar, the minimum confidence value was set to 0.1 and the maximum value to 1.0. Confidence settings define how often the rule came out to be true. Again, items with confidence value lower than the minimum value will be excluded from the analysis. Confidence is calculated using the following equation:

$$\text{Confidence } (A \Rightarrow B) = p(B \mid A) = \text{Support } (A, B) / \text{Support } (A) \tag{3}$$

Additional, it has been defined that the maximum number of items in an item set is 10.

It has to be emphasized that there are no strict rules in the literature that minimum support value; minimum confidence value or the maximum number of items in an item set should be selected [37]. Other authors in their work use subjective criteria for selecting association rules [38], [39]. Therefore, the limits are here used as described before because the experiments with the different level of metrics indicated that they result in interesting rules.

4. Results

4.1 Decision tree

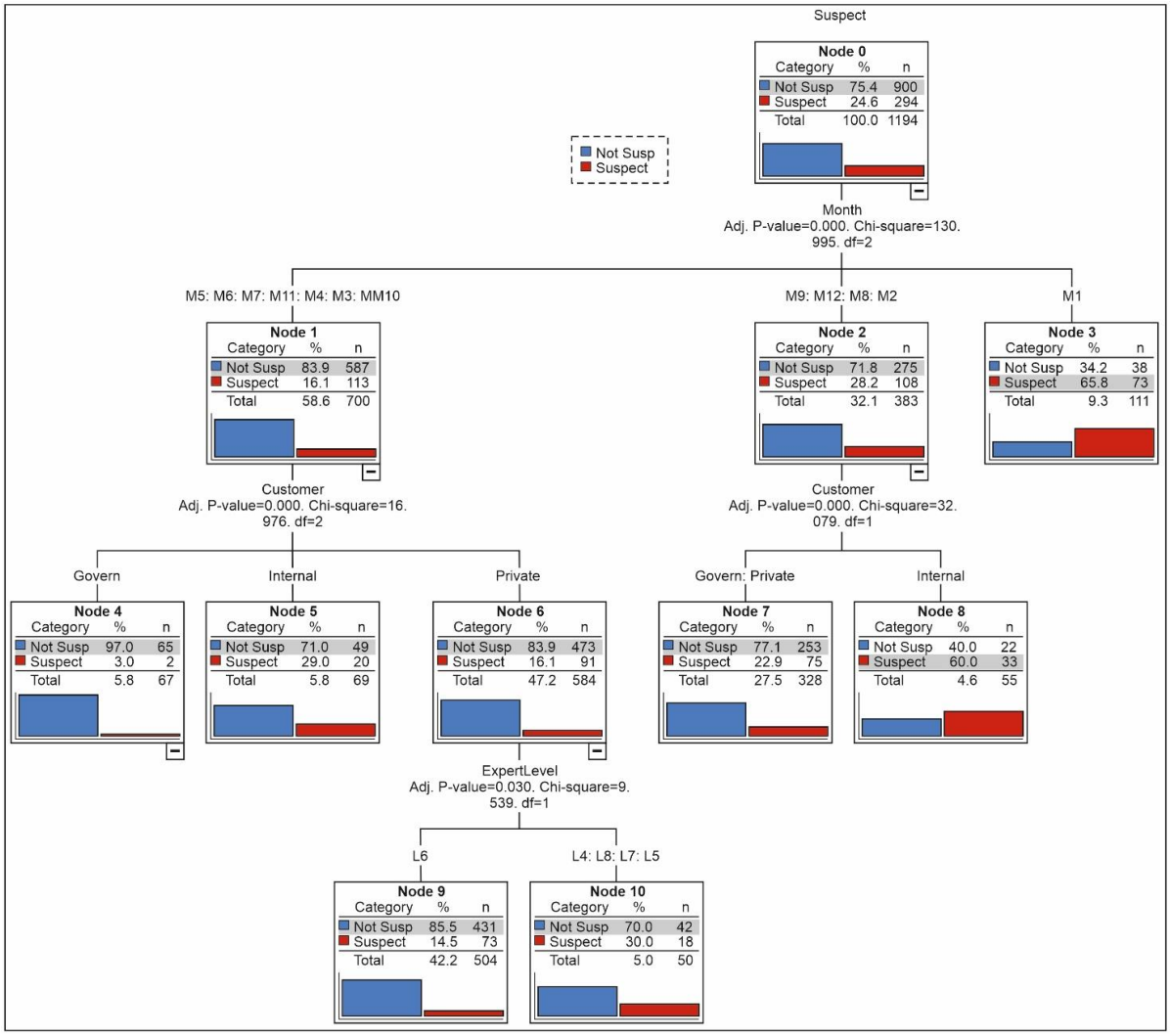
According to defined settings, the CHAID decision tree is developed (Figure 1). The resulting CHAID decision tree has 3 levels and overall 11 nodes out of which seven are considered as a terminal (they do not split further). Figure 1 also reveals that variables Month, Customer and ExpertLevel had the highest level of statistical significance and therefore they are used in building the classification tree.

The variable used for branching on the first level is the variable Month, which turned out to be statistically significant at the level of 1% (chi-square=130.995, p-value<0.001). This branching resulted in three new nodes (Node 1, Node 2, and Node 3). Node 1 includes categories M3, M4, M5, M6, M7, M10, and M11. That way Node 1 consists of 700 working-hours claims out of which 587 or 83.9% are treated as non-suspected whereas 113 or 16.1% are suspected. Node 2 includes the following categories of the variable Month: M2; M8; M9; and M12. Consequently, Node 2 has in total 383 working-hours claims out of which 275 or 71.8% are non-suspected whereas 108 or 28.2% are suspected. Node 3 includes only the category M1 and only at this node, the share of suspected working-hours claims (65.8%) is greater than the share of non-suspected working-hours claims (34.2%).

The variable Customer was used for branching on the second level. According to Figure 1, branching resulted in five new nodes with three of them (Node 4, Node 5, and Node 6) coming out from Node 1 and two of them (Node 7 and Node 8) from Node 2. Both branching processes are highly statistically significant at 1% (from Node 1 – chi-square=16.976, p-value<0.001; from Node 2 – chi-square=32.079, p-value<0.001). Node 4 includes only 67 customers of government institutions out of which 65 or 97.0% are connected with non-suspected working-hours claims, and two or 3.0% are connected with suspected working-hours claims. Node 5 consists of 69 customers of internal projects out of which 49 or 71.0% are connected with non-suspected working-hours claims and 20 or 29.0% are connected with suspected working-hours claims. Node 6 includes only customers of private enterprises, and it is the largest one among nodes of the second level. There are 473 or 83.9% customers of private enterprises that are connected with non-suspected working-hours claims and 91 or 16.1% that are connected with suspected working-hours claims. On the other hand, Node 7, which is related to Node 2, includes customers of government institutions and customers of private enterprises together. It has been shown that out of 328 customers 253 or 77.1% are non-suspected whereas 75 or 22.9% are suspected for working-hours claim fraud. Node 8 includes only customers of internal projects. When nodes of the second level are observed, it can be concluded that only at this node the share of suspected working-hours claims (60.0) is higher than the share of non-suspected working-hours claims (40.0%).

The third level branching variable is the variable ExpertLevel. This variable was used to branch Node 6 further into two new nodes (Node 9 and Node 10). This branching process is statistically significant at the 5% level (chi-square=9.539, p-value=0.030). Node 6 consists only of consultants with the expert level L6 whereas consultants with levels L4, L5, L7, and L8 can be found in Node 10. Node 9 is considerably larger than Node 10 and includes 431 or 85.5% non-suspected working-hours claims and 73 or 14.5% suspected working-hours claims. Furthermore, it has to be emphasized that Node 9 includes 42.2% of all observed working-hours claims whereas Node 10 includes only 5.0% of them. Therefore, Node 10 includes 60 working-hours claims out of which 42 or 70% are non-suspected whereas 18 or 30.0% are suspected.

The classification matrix, shown in Table 9, compares the observed and the predicted status of working-hours claims. The used algorithm was correct in 93.3% of cases for the non-suspect working-hour claims. In other words, out of 900 non-suspected working-hours claims, the algorithm has correctly classified 840 of them, whereas 60 working-hours claims were wrongly classified. The successfulness of the algorithm seems to be quite low in relation to suspected working-hours claims. Namely, out of 294 suspected working-hours claims, the algorithm correctly classified 106 working-hours claims or 36.1%.



Source: Authors' work, based on the internal data source.

Figure 1. CHAID decision tree

Table 9. The number of hours claimed – variable NoHoursCoded

Observed classification	**Predicted classification**		
	Non-suspect	**Suspect**	**Percent correct**
Non-suspect	840	60	93.3%
Suspect	188	106	36.1%
Overall percentage	86.1%	13.9%	79.2%

Source: Authors' work, based on the internal data source.

4.2 Link analysis

Using the selected metrics (minimum support value of 0.2; minimum confidence value of 0.1 and the maximum number of items in an item set of 0), the association rules have been developed. Table 10 presents the most frequent itemsets that contain Suspect item, indicating that the suspectable amount of working hours has been claimed. The item Suspect alone, with the frequency of 235, appears in the 27.71% of itemsets. Item Suspect in combinations with other items, such as Private, Domestic 51-100 and L6 can also be found in a significant number of projects. Consequently, it can be concluded that suspected working-hour claims are very closely related and linked with customers from private enterprises, with domestic consultants, with cost per hour between 51 and 100 EUR, and with expert level L6. Those relations are presented graphically in Figures 2 and 3 as well.

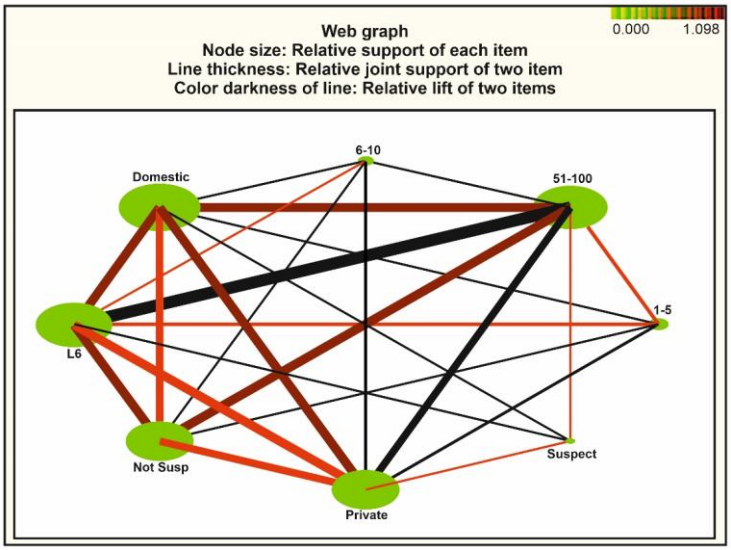
Table 10. Frequent itemsets that contain Suspect item

Frequent itemsets	Number of items	Frequency	Support (%)
Suspect	1	235	27.712
51-100, Suspect	2	225	26.533
51-100, L6, Suspect	3	221	26.061
L6, Suspect	2	221	26.061
Domestic, Suspect	2	220	25.943
51-100, Domestic, Suspect	3	210	24.764
51-100, Domestic, L6, Suspect	4	206	24.292
Domestic, L6, Suspect	3	206	24.292
Private, Suspect	2	193	22.759
Domestic, Private, Suspect	3	185	21.816
51-100, Private, Suspect	3	183	21.580
L6, Private, Suspect	3	180	21.226
51-100, L6, Private, Suspect	4	180	21.226
51-100, Domestic, Private, Suspect	4	175	20.636
51-100, Domestic, L6, Private, Suspect	5	172	20.283
Domestic, L6, Private, Suspect	4	172	20.283

Source: Authors' work, based on the internal data source.

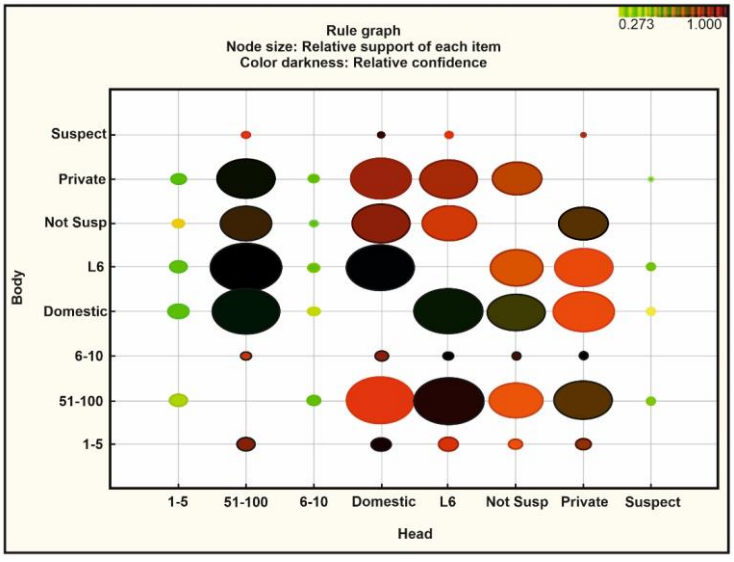
Figure 2 presents a Web graph of items generated by link analysis. Node size indicates the relative support for each item, line thickness relative joint support of two items, and color darkness of line a relative lift of two items. It can be observed that the most important nodes are related to the domestic experts, non-suspected claims, the lowest level of expertise (L6), private customers, and one of the low level of hourly paid rate (51-100 EUR). The strongest joint support is for the claims that are non-suspected and the domestic experts, the lowest level of expertise (L6), private customers, and one of the low level of hourly paid rate (51-100 EUR). As expected the darkest line presents the strength of the relationship between the lowest level of expertise (L6) and one of the low levels of hourly paid rate (51-100 EUR).

Figure 3 presents a rule graph of items generated by link analysis. Node size presents relative support of each item, and color darkness relative confidence. Again, the rule with the highest confidence and support is the relationship between the lowest level of expertise (L6) and one of the low level of hourly paid rate (51-100 EUR). It can be noted that the rules that contain the item Suspect are presented with small node sizes, and include the relationships between the item Suspect and the low level of hourly paid rate (51-100 EUR), domestic experts, the lowest level of expertise (L6), and private companies as customers.



Source: Authors' work, based on the internal data source.

Figure 2. Web graph of items generated by link analysis



Source: Authors' work, based on the internal data source.

Figure 3. Rule graph of items generated by link analysis

Table 11 presents association rules with the item Suspect in the body. The first rule shows that 26.53% of working-hours claims are suspected and with cost per hour between 51 and 100 EUR. Furthermore, it seems that 95.75% suspected working-hours claims are with cost per hour between 51 and 100 EUR. The second and third rules resulted in the same support and confidence levels.

Table 11. Frequent association rules with the item Suspect in the body

Body	==>	Head	Support (%)	Confidence (%)	Lift
Suspect	==>	51-100	26.533	95.745	1.052
Suspect	==>	51-100, L6	26.061	94.043	1.042
Suspect	==>	L6	26.061	94.043	1.042
Suspect	==>	Domestic	25.943	93.617	0.985
Suspect	==>	51-100, Domestic	24.764	89.362	1.031
Suspect	==>	51-100, Domestic, L6	24.292	87.660	1.021
Suspect	==>	Domestic, L6	24.292	87.660	1.021
Suspect	==>	Private	22.759	82.128	0.992
Suspect	==>	Domestic, Private	21.816	78.723	0.995
Suspect	==>	51-100, Private	21.580	77.872	1.025
Suspect	==>	51-100, L6, Private	21.226	76.596	1.016
Suspect	==>	L6, Private	21.226	76.596	1.016
Suspect	==>	51-100, Domestic, Private	20.637	74.468	1.027
Suspect	==>	51-100, Domestic, L6, Private	20.283	73.191	1.017
Suspect	==>	Domestic, L6, Private	20.283	73.191	1.017

Source: Authors' work, based on the internal data source.

Table 12 presents association rules with the item Suspect and one more item in the Body. If items Suspect and Private are in the Body, the strongest association is achieved with item Domestic. In that case, 21.82% of working-hours claims are suspected working-hours claims, with customers from private enterprises and with domestic consultants. It appears that 95.86% of suspected working-hours claims with customers from private enterprises include domestic consultants. If items Suspect and L6 are put together in the Body, the strongest association is achieved with item 51-100. It has been shown that all suspected working-hours claims with expert level L6 are related to cost per hour between 51 and 100 EUR. If items Suspect and Domestic are together in the Body, again the strongest association is achieved with item 51-100. However, 95.46% of suspected working-hours claims with domestic consultants have a cost per hour between 51 and 100 EUR.

Association rules with the item Suspect and two or more items in the Body are presented in Table 13. Suspected working-hours claims with customers from private enterprises and with expert level L6 have a cost per hour between 51 and 100 EUR. The same conclusion can be brought when items Domestic, L6 and Suspect are associated with item 51-100; and when items Domestic, L6, Private and Suspect are associated with item 51-100.

Table 12. Association rules with the item Suspect and one more item in the Body

Body	==>	Head	Support (%)	Confidence (%)	Lift
Private, Suspect	==>	Domestic	21.816	95.855	1.008
Private, Suspect	==>	51-100	21.580	94.819	1.042
Private, Suspect	==>	51-100, L6	21.226	93.264	1.034
Private, Suspect	==>	L6	21.226	93.264	1.034
Private, Suspect	==>	51-100, Domestic	20.637	90.674	1.046
Private, Suspect	==>	51-100, Domestic, L6	20.283	89.119	1.038
Private, Suspect	==>	Domestic, L6	20.283	89.119	1.038
L6, Suspect	==>	51-100	26.061	100.000	1.098
L6, Suspect	==>	51-100, Domestic	24.292	93.213	1.075
L6, Suspect	==>	Domestic	24.292	93.213	0.981
L6, Suspect	==>	51-100, Private	21.226	81.448	1.072
L6, Suspect	==>	Private	21.226	81.448	0.984
L6, Suspect	==>	51-100, Domestic, Private	20.283	77.828	1.073
L6, Suspect	==>	Domestic, Private	20.283	77.828	0.984
Domestic, Suspect	==>	51-100	24.764	95.455	1.049
Domestic, Suspect	==>	51-100, L6	24.292	93.636	1.038
Domestic, Suspect	==>	L6	24.292	93.636	1.038
Domestic, Suspect	==>	Private	21.816	84.091	1.016
Domestic, Suspect	==>	51-100, Private	20.637	79.545	1.047
Domestic, Suspect	==>	51-100, L6, Private	20.283	78.182	1.038
Domestic, Suspect	==>	L6, Private	20.283	78.182	1.038
51-100, Suspect	==>	L6	26.061	98.222	1.089
51-100, Suspect	==>	Domestic	24.764	93.333	0.982
51-100, Suspect	==>	Domestic, L6	24.292	91.556	1.066
51-100, Suspect	==>	Private	21.580	81.333	0.982
51-100, Suspect	==>	L6, Private	21.226	80.000	1.062
51-100, Suspect	==>	Domestic, Private	20.637	77.778	0.983
51-100, Suspect	==>	Domestic, L6, Private	20.283	76.444	1.063

Source: Authors' work, based on the internal data source.

Table 13. Association rules with the item Suspect and two or more items in the Body

Body	==>	Head	Support (%)	Confidence (%)	Lift
L6, Private, Suspect	==>	51-100	21.226	100.000	1.098
L6, Private, Suspect	==>	51-100, Domestic	20.283	95.556	1.102
L6, Private, Suspect	==>	Domestic	20.283	95.556	1.005
Domestic, Private, Suspect	==>	51-100	20.637	94.595	1.039
Domestic, Private, Suspect	==>	51-100, L6	20.283	92.973	1.031
Domestic, Private, Suspect	==>	L6	20.283	92.973	1.031
Domestic, L6, Suspect	==>	51-100	24.292	100.000	1.098
Domestic, L6, Suspect	==>	51-100, Private	20.283	83.495	1.099
Domestic, L6, Suspect	==>	Private	20.283	83.495	1.009
Domestic, L6, Private, Suspect	==>	51-100	20.283	100.000	1.098
51-100, Private, Suspect	==>	L6	21.226	98.361	1.090
51-100, Private, Suspect	==>	Domestic	20.637	95.628	1.006
51-100, Private, Suspect	==>	Domestic, L6	20.283	93.989	1.095
51-100, L6, Suspect	==>	Domestic	24.292	93.213	0.981
51-100, L6, Suspect	==>	Private	21.226	81.448	0.984
51-100, L6, Suspect	==>	Domestic, Private	20.283	77.828	0.984
51-100, L6, Private, Suspect	==>	Domestic	20.283	95.556	1.005
51-100, Domestic, Suspect	==>	L6	24.292	98.095	1.087
51-100, Domestic, Suspect	==>	Private	20.637	83.333	1.007
51-100, Domestic, Suspect	==>	L6, Private	20.283	81.905	1.087
51-100, Domestic, Private, Suspect	==>	L6	20.283	98.286	1.089
51-100, Domestic, L6, Suspect	==>	Private	20.283	83.495	1.009

Source: Authors' work, based on the internal data source.

5. Conclusions

A case study analysis was conducted using data related to suspected working-hour claims in one project-based company. We aim to identify the relationship of the suspect working-hour claims with selected variables, related to characteristics of customers, consultants, and work conducted (e.g., private and government customers; domestic or foreign consultants; the month of the work conducted and hourly rate). We develop two data mining models that identified the following characteristics of fraudulent working-hour claims: customers are private enterprises, consultants are of domestic origin and with the lowest level of expertise, and the cost of the consulting services are within the lowest range. First, the CHAID decision tree was developed in order to determine the relationships between numerous characteristics of the project (e.g., characteristics of the client and the expert), and suspect working-hour claims. The results of the decision tree showed a general rate of nearly 80% of correct classification. Second, the link analysis was used for the detection of potentially suspect working-hours claims. Both decision tree and link analysis indicate that suspected working-hours claims are related to customers from private enterprises, domestic consultants, cost per hour between 51 and 100 EUR, and the lowest level of expertise.

This paper contributes to the growing body of work that investigates internal fraud prevention and detection. However, most of the work conducted in this area is focused on the analysis of financial reports and accounting fraud [5], [6], [7], while in our work, we focus to project-based organizations. This research has demonstrated the use of a data mining methodology to detect internal fraud. Our proposition was that it is possible to develop a data mining application that could be useful for project-based organizations in predicting and detecting fraudulent working-hour claims. Although the decision tree algorithm is more efficient in predicting non-suspect working-hour claims than in suspect ones, and the confidence and support levels for suspect claims were rather low, the management from the company confirmed that the information derived is valid to them since it provided new insight into the characteristics of suspect working-hour claims. This information allows them to focus their efforts on the following categories identified by the decision tree as the most likely to be suspected: working-hour claims submitted in M1 by the internal experts. In addition, the general rate of correct classification of 79.2% can be observed as quite good [40]. Based on the presented results, it can be concluded that the decision tree and link analysis are recommended for use as a supportive instrument for the detection of suspect working-hour claims, in combination with other human-based and machine-based methods.

Our research has significant practical implications. Considering that auditors need non-accounting and non-financial data with no external standards to apply, it is likely that auditors will need to develop their own set of procedures to determine the quality of non-financial data [41]. Therefore, it is important that organizations expand usage and potentials of different data mining techniques, which could help them to be more effective and efficient in investigating and preventing internal fraud [17]. Project-based organizations often learn implicitly from experience [42], aiming to capture and share project-based knowledge, thus indicating that data mining could be widely accepted in their learning-oriented cultures [43]. One of the possible operationalizations of our work in this direction is the usage of SQL code that is generated by the software used for the development of the CHAID decision tree (Appendix 1), which can be used for the development of the solution for automatic internal fraud-detection.

Limitations of the paper derive mainly from sample characteristics since we presented one case study for one specific company and the usage of two data mining methods. Therefore, in order to test if our results are generally applicable, future research should be focused on datasets from organizations from different settings, using a broader set of data mining techniques, which would improve the knowledge regarding discovering patterns in internal fraud in project-based organizations using data mining techniques.

Acknowledgments

This paper extends the research on the internal fraud using the CHAID decision tree that was presented on CENTERIS - Conference on ENTERprise Information Systems [11]. This research has been fully supported by the Croatian Science Foundation under the PROSPER (Process and Business Intelligence for Business Performance) project (IP-2014-09-3729).

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Appendix A. Selected SQL equations generated for the implementation of the CHAID decision tree

/* Node 4 */. DO IF (Month NE "M9" AND Month NE "M12" AND Month NE "M8" AND Month NE "M2" AND Month NE "M1") AND (Customer EQ "Govern"). COMPUTE nod_001 = 4. COMPUTE pre_001 = 'Not Susp'. COMPUTE prb_001 = 0.970149. END IF. EXECUTE.

/* Node 5 */. DO IF (Month NE "M9" AND Month NE "M12" AND Month NE "M8" AND Month NE "M2" AND Month NE "M1") AND (Customer EQ "Internal"). COMPUTE nod_001 = 5. COMPUTE pre_001 = 'Not Susp'. COMPUTE prb_001 = 0.710145. END IF. EXECUTE.

/* Node 9 */. DO IF (Month NE "M9" AND Month NE "M12" AND Month NE "M8" AND Month NE "M2" AND Month NE "M1") AND (Customer NE "Govern" AND Customer NE "Internal") AND (ExpertLevel NE "L4" AND ExpertLevel NE "L8" AND ExpertLevel NE "L7" AND ExpertLevel NE "L5"). COMPUTE nod_001 = 9. COMPUTE pre_001 = 'Not Susp'. COMPUTE prb_001 = 0.855159. END IF. EXECUTE.

/* Node 10 */. DO IF (Month NE "M9" AND Month NE "M12" AND Month NE "M8" AND Month NE "M2" AND Month NE "M1") AND (Customer NE "Govern" AND Customer NE "Internal") AND (ExpertLevel EQ "L4" OR ExpertLevel EQ "L8" OR ExpertLevel EQ "L7" OR ExpertLevel EQ "L5"). COMPUTE nod_001 = 10. COMPUTE pre_001 = 'Not Susp'. COMPUTE prb_001 = 0.700000. END IF. EXECUTE.

/* Node 7 */. DO IF (Month EQ "M9" OR Month EQ "M12" OR Month EQ "M8" OR Month EQ "M2") AND (Customer NE "Internal"). COMPUTE nod_001 = 7. COMPUTE pre_001 = 'Not Susp'. COMPUTE prb_001 = 0.771341. END IF. EXECUTE.

/* Node 8 */. DO IF (Month EQ "M9" OR Month EQ "M12" OR Month EQ "M8" OR Month EQ "M2") AND (Customer EQ "Internal"). COMPUTE nod_001 = 8. COMPUTE pre_001 = 'Suspect'. COMPUTE prb_001 = 0.600000. END IF. EXECUTE.

/* Node 3 */. DO IF (Month EQ "M1"). COMPUTE nod_001 = 3. COMPUTE pre_001 = 'Suspect'. COMPUTE prb_001 = 0.657658.

END IF. EXECUTE.

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ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
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