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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.

We are pleased to bring you the first number of the 11th volume of IJISPM. In this issue, readers will find important contributions to digital transformation, Robotic Process Automation, visual analytics, and change requests management.

The first article, “Supporting the digital transformation of SMEs — trained digital evangelists facilitating the positioning phase”, is authored by Jukka Kääriäinen, Leila Saari, Maarit Tihinen, Sari Perätalo, and Timo Koivumäki. As digital transformation (DT) sweeps over society, the exploitation of digital solutions is obvious, especially for large enterprises. Unfortunately, small- and medium-sized enterprises (SMEs) struggle with DT because of limited resources, understanding, and implementation skills. Thus, SME companies need both methods and tools to proceed with DT as well as support to exploit them. This article presents a study in which adult learners with professional experience are trained to use a digitalization development method and tools to analyze target organizations’ digitalization state and identify improvement ideas. Thirty trained digital evangelists used the tools and methods while conducting digitalization status analyses in eleven organizations. The study results show that the method and tools work in the context presented in this research. The study’s findings are beneficial for educational professionals interested in educating students toward helping SME organizations along their digitalization pathway.

The title of the second article is “Employees’ perception of value-added activity increase of Robotic Process Automation with time and cost efficiency: a case study”, which is authored by Arafat Salih Aydıner, Selman Ortaköy, and Zehra Özsürünç. Drawing upon the theory of Task-Technology Fit, this study explores the emerging consequences of Robotic Process Automation (RPA). Data related to the time and cost of processes before and after the RPA implementation were collected and descriptively analyzed. Even though time and cost efficiency improvements occurred in 50 out of 54 of the processes, the results indicated no labor reduction after the RPA implementation and no cost reduction in some business units, contrary to reports in the literature. To investigate what happened to the human resource environment, the authors surveyed 106 employees affected by the implementation of RPA. No variance was found between the characteristics of the employees and the changes in the working environment. However, the descriptive results of the survey revealed that employees’ perception of value-added activities increased. These results provided that considering RPA as a routine process without calculating the strategic value creates process-oriented transformation with a lack of time and cost-efficiency.

The third article, authored by Alireza Khakpour, Ricardo Colomo-Palacios, and Antonio Martini, is entitled “Towards a framework for developing visual analytics in supply chain environments”. Visual Analytics (VA) has shown significant importance for Supply Chain (SC) analytics. However, SC partners still have challenges incorporating it into their data-driven decision-making activities. A conceptual framework for the development and deployment of a VA system may provide an abstract, platform-independent model for the whole process of VA, covering requirement specification, data collection and pre-processing, visualization recommendation, visualization specification and implementation, and evaluations. In this paper, the authors propose such a framework based on three main aspects: 1) Business view, 2) Asset view, and 3) Technology view. Each of these views covers a set of steps to facilitate the development and maintenance of the system in its context. The framework follows a process structure that comprises activities, tasks, and people. The final output of the whole process is the VA as a deliverable. This facilitates the alignment of VA activities with business processes and decision-making activities. The authors presented the framework’s applicability using an actual usage scenario and left the implementation of the system for future work.

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“Improving the evaluation of change requests using past cases” is the fourth article and is authored by Otávio da Cruz Mello and Lisandra Manzoni Fontoura. As one of the leading causes of project failures, requirements changes are inevitable in any software project. The authors propose an intelligent approach to facilitate the risk analysis of a change request by providing information about past cases found in similar change requests, the solutions adopted, and a support tool. The proposed approach uses case-based reasoning to retrieve previous cases similar to the current case. This approach also uses association rules to analyze patterns in the dataset and calculate the probability of risks associated with change requests. The authors validate the proposal in a case study by analyzing the most frequent challenges in change management and considering how it can solve or minimize such problems. Results show that the proposed approach successfully assists decision-making, predicts potential risks, and suggests coherent solutions to the user. The authors have developed a support tool to evaluate this approach in practice with experts and obtained four different outcomes. The use of case-based reasoning and association rules has proven advantageous in change management despite validity threats associated with the small number of test cases and experts involved.

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

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

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

The Editor-in-Chief,

João Varajão

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

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Supporting the digital transformation of SMEs — trained digital evangelists facilitating the positioning phase

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Supporting the digital transformation of SMEs — trained digital evangelists facilitating the positioning phase

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Abstract:
As digital transformation (DT) sweeps over society, the exploitation of digital solutions is obvious, especially for large enterprises. Unfortunately, small- and medium-sized enterprises (SMEs) struggle with DT because of limited resources, understanding, and implementation skills. Thus, SME companies need both methods and tools to proceed with DT as well as support to exploit them. This article presents a study in which adult learners with professional experience are trained to use a digitalization development method and tools to analyze target organizations' digitalization state and identify improvement ideas. Thirty trained digital evangelists used the tools and methods while conducting digitalization status analyses in eleven organizations. The study results show that the method and tools work in the context presented in this research. The study's findings are beneficial for the educational professionals interested in educating students towards helping SME organizations along their digitalization pathway.

Keywords:
digitalization; digital transformation; small and medium-sized enterprise; digital transformation model; digital maturity; digital evangelist.

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1. Introduction

Digitalization has been commonly identified as one of the major trends and drivers for changing society and creating business opportunities in the near- and long-term future [1]–[3]. Table 1 presents the digital transformation playground with three drivers: business model-related concepts, other ICT and digitalization trends, and mainstream concepts (enabling technologies) [4].

Table 1. Digital transformation playground (modified based on Pihir et al. [4])

Business model–related concepts	Other ICT and digitalization trends	Mainstream concepts; enabling technologies
▪ Improvements, increased effectiveness/efficiency ▪ Ecosystems/green tech ▪ New business models ▪ New services, competencies, skills ▪ Customer experience, journey ▪ New alliances	▪ Social media and platforms ▪ Artificial intelligence and gamification ▪ Meta modeling ▪ IoT, Big Data, and analytics ▪ Virtual technologies and knowledge management ▪ Robotics and autonomous systems	▪ Cloud technologies ▪ Mobile technologies ▪ Reference models ▪ Enterprise resource planning and customer relationship management ▪ Supply chain management and data warehousing ▪ Business process and performance management

The business benefits of digitalization are widely recognized and reported [5], [6]. Even so, smaller companies often struggle to reach the potential benefits. The identified challenges can relate to, for example, a high investment cost, lack of time and knowledge related to technology implementation and business model innovation, unclear business benefits, lack of standards, and unclear effects on value chains and customer behavior [3], [7]–[9]. This highlights that the identified challenges are multifaceted, complex, and still largely unsolved. Excess inertia related to SME digitalization has also been recognized as one of the main economic challenges. The European Digital SME Alliance has highlighted the need to increase the adoption of digital transformation via supporting measures [10], [11].

One way to increase digital support for SMEs is to enhance academia's research impact and knowledge transfer and emphasize the role of universities in advancing both economic growth and technical change [12]. According to Chang [13], universities' role within the innovation system is vital and will increase in the future. To pursue this goal in the European Union, changes were made in national and international research policies and research funding instruments, emphasizing higher societal impact creation through interaction with different actors, including SMEs. However, there is still a significant lack of understanding of how to transfer research results efficiently to companies on a large scale [13], [14]. Despite the substantial research on digital transformation, there is a lack of practical grassroots-level, tool-supported approaches that are suitable and carefully tested to support the digital transformation of SMEs [15]. It has been stated that there is a need for a process model incorporating external support units into DT work to assist SMEs in their digitalization efforts [16].

In order to address the need of SMEs for support tools and mechanisms for DT, this article focuses on how a digitalization support service developed in a research project could be offered to SMEs with the needed support. More precisely, the article examines how adult learners with professional experience can be trained to act as digital evangelists to facilitate the improvement of digitalization in companies.

The structure of the article is as follows. The following section comprises the literature review, followed by Section 3, which describes the research design. Section 4 presents the results gathered from the research. The discussion is in Section 5, and section 6 concludes the article and presents proposals for future research.

2. Related research

Digital transformation (DT) is an emerging trend and has been considered in several literature reviews. Ograen and Herciu [17] found 787 DT papers published during 2003–2020; more than three-quarters of the articles were published in 2019 and 2020, and 47 papers had "SME" as a keyword. DT is a rich concept, not just an IT issue [18]. Pihir et al. [4] reviewed DT literature in 2019 and found the top three publication domains: computer science, business or economics, and engineering. Another DT literature review by Hausberg et al. [19] identified three dominant areas (finance, marketing, and innovation management) and nine streams or application domains. The literature review by Ograen and Herciu [17] defined digitalization and DT as follows:

> *Digitization is the first step of a complex process (with quite significant impacts) of digital transformation leading towards a digital economy—where digitalization, while making use of artificial intelligence (alongside automation, big data, cloud computing, digital twin, internet of things), is capitalizing on the digital technology.*

The literature review by Zhu et al. [20] highlights three important themes in preparing DT for firms. First, it is essential to formulate the right digital strategy because there are significant differences between digital business strategy and digital transformation strategy regarding objectives, content, and functions. A digital business strategy focuses on macro goals, and a DT strategy focuses on a specific DT implementation process. Second, adopting a digital technology combination suitable for the firm's development is important. This derives from the fact that different digital technologies and technological combinations impact firms differently. Third, regularly evaluating and adjusting the firm's digital strategy is crucial. Digitalization is not just about bringing new technology into use; these new technologies impact firms at a strategic, operational, and industrial level. Thus, the role of practitioners who understand DT strategies and can select the right digital technologies is vital [20].

Horlacher and Hess [21] describe the six roles of company information system managers as spokesperson, monitor, entrepreneur, resource allocator, leader, and liaison. Further, they reveal the tasks of the chief digital officer in four companies. These tasks relate to, for instance, the definition of the digital strategy, coordinating DT across the company, conducting workshops and employee training sessions, and visiting events to look for emerging innovations. In these companies, the chief digital officers drove the digital transition and acted as "digital evangelists" [21]. In addition, Singh and Hess [22] study how chief digital officers orchestrate the DT of their companies. Three role types were identified: entrepreneur, digital evangelist, and coordinator. They state that digital evangelists need good inspiration and digital pioneering skills to promote DT effectively [22].

DT in companies requires special preparation (e.g., analyzing the existing state) and guidance before implementation. The process should balance generic phases and adaptation of the DT to each company's context [23]. Most small companies move directly into action and apply solutions without a clear understanding of digital technologies [24]. There is a need to build systematics toward DT. Therefore, the process of how to support the DT of companies has received attention in the research community. Table 2 summarizes examples of research that has contributed to a digital transformation model or process, has SME cases or viewpoints, or provides tools or methods for SMEs to apply. A variety of approaches have been developed to support digital transformation, such as a two-phase procedure model to show how publicly funded organizations can support SME digitalization [16], a transformation process framework [25], a DT process model by an SME entrepreneur [26], a two-phase DT model for the SME sector [27], and a four-phase digital transformation model [3].

The limited resources of SMEs must be considered when their digitalization activities are supported. SMEs may not have the necessary resources, such as know-how, for digitalization ([26], [28]) on their own and cannot afford expensive consultants [16]. Thus, one approach to overcome this shortage is using free external public-sector facilitators, which Barann et al. [16] present as a means for the DT of SMEs. They added that the DT method needs to be practical and not an abstract model.

Ulas [28] explains how governmental intervention in the Accelerating Programme of Digital Transformation in Industry was established in Turkey to include external support from competence centers or research institutes. This kind of external support by research institutes is also reported in Kääriäinen et al. [15], in which research scientists carried out the digitalization status analysis using a pre-defined method and tools for a set of SME companies. Pelletier and Cloutier [29] recognize the limited resources of SMEs (human, material, and financial) and propose public and support organizations to encourage companies to initiate rapid DT and elaborate a deliberate digital strategy. The public sector could use education to raise companies' digital knowledge [30] and to spread information about digitalization and encourage a positive attitude toward it in companies [31].

Table 2. Examples of research contributions to DT models, SME focus, and tools or methods

Title	**DT model or process**	**SME cases or viewpoints**	**Tools or methods for SMEs to apply**
Supporting digital transformation in small and medium-sized enterprises: a procedure model involving publicly funded support units [16]	Two-phase procedure model: orientation and iterative transformation		Eleven requirements for DT support models for SMEs
Collaborative approach to digital transformation (CADT) model for manufacturing SMEs [32]	Collaborative approach based on three sub-objectives	One case of collaboration between two manufacturing SMEs	
Role of government to enhance digital transformation in small service business [30]	Cognizant's digital transformation framework	Ten SMEs were selected by using judgment sampling and quota sampling	A model for drivers, barriers, and government support of digital transformation
Fostering digital transformation of SMEs: a four levels approach [33]	Four-level approach: awareness, enquirement, collaboration, and transformation	Four case companies	Roadmap
Applying the positioning phase of the digital transformation model in practice for SMEs: toward systematic development of digitalization [15]	Digital transformation process with four phases: positioning, current state analysis, roadmap, and implementation	Nineteen SMEs were guided through the positioning phase	Tools such as DigiMaturity, DigiSWOT, and DigiTriangle are available on ApuaDigiin.fi web service
Digital transformation by SME entrepreneurs: a capability perspective [26]	A process model of digital transformation by an SME entrepreneur	7 SMEs, cross-border e-commerce with a digital platform	
Leveraging digital technology to transform accounting function: case study of an SME [25]	Transformation process framework based on Lewin's (1951) theory of change	One SME accounting function case	
Tackling the digitalization challenge: how to benefit from digitalization in practice [3]	Four-stage model for digital transformation	One SME background case	SWOT tool as part of the first stage
Barriers to digital servitization in French manufacturing SMEs [7]		Eight manufacturing SME servitization cases	
Conceptualizing digital transformation in SMEs: an ecosystemic perspective [29]	Five-step model		Entrepreneurs' Strategic Action Go-Zones
Measures for successful digital transformation of SMEs [34]	Eighteen different digitalization measures	Eleven SME case companies	Acatech Industry 4.0. Maturity Index
The concept of building a digital transformation model for enterprises from the SME sector [27]	Two-phase digital transformation model for the SME sector	One SME case	A digitization index with 21 subindexes, Ichikawa diagram, SWOT analysis
Survival in the digital age – a framework for formulating a digital transformation strategy in an SME [35]		Seven SME cases; formulating digital transformation strategy	Four strategic dimensions in the digital transformation framework with 14 questions

One substantial effort to increase the digitalization of SME companies is identification and launching the European Commission’s European Digital Innovation Hubs (EDIHs) [36]. These will function as one-stop shops that help companies (especially SMEs) dynamically respond to digital challenges and become more competitive. Sassanelli et al. [37] consider the support given to SMEs by DIHs, the predecessor of EDIHs. They propose the Data-Driven Business-Ecosystem-Skills-Technology (D-BEST) service portfolio for DIHs to support the DT of SMEs. The service-oriented approach enables the communication between the customer, provider, and registry. Furthermore, the service portfolio should include a service catalog and a pipeline containing services under development. Efforts like this are essential support functions for the competitiveness of European companies because digital readiness varies in the companies [38].

Despite the substantial research on DT, there is a lack of practical grassroots-level, tool-supported approaches that are suitable and carefully tried and tested for supporting the DT of SMEs [15], [16]. DT projects are complex and incorporate multiple factors [39]. DT is not only a technical achievement; solid top management support [40] and a corporate attitude that supports change and transformation [41] are necessary to get the most out of it. In addition, organizational structures may need to be changed or aligned during the digitalization process [42]. In a digital setting, firms should be able to recognize and respond to external environmental factors quickly. However, the challenge is that SMEs do not know how to begin with development [41]. It has also been stated that there is a need for process models incorporating external support units into digital transformation work to support SMEs in their digitalization efforts [16]. To bridge the gap, Kääriäinen et al. [15] constructed a digitalization support service, ApuaDigiin.fi (“help for digitalization” in Finnish), and a network to maintain it. The model and tools of ApuaDigiin have been published as Interreg Europe Good Practices [43], [44]. In this article, we demonstrate how the positioning phase (digitalization status analysis) method and tools of the DT model could be utilized by an external support unit (educational partner) to help SMEs in their digitalization by guiding adult learners to carry out digitalization status analysis for the selected target organizations.

3. Research design

This research focuses on studying how adult learners can be equipped to analyze the state of digitalization of target organizations, providing an important starting point for their DT. First, the section presents the method and tools of digitalization status analysis, namely the positioning phase of the DT model. Then we introduce different usage scenarios for the method and tools and describe the kind of usage scenario in this study—the digital evangelist approach—in more detail. Finally, the research setting for testing this approach is described.

3.1 Positioning phase of the digital transformation process

This research is part of our longer-term research path related to DT that began in 2015 and resulted in a conceptual framework of the DT model [3], [45], digital maturity model, and tool [46]. In 2018 and 2019, ApuaDigiin, a support service for SME digitalization, was built and tested to allow free-of-charge access for companies or other organizations to utilize digitalization support tools [47]. At the same time, the ApuaDigiin network consisting of educational partners, regional business development authors, research organizations, and associations was established. Various tools were added to the service to support the digitalization pathway of SME companies and provide a platform for sharing these tools, related guidance, and digitalization experiences. The steps of the DT model comprise positioning, a current state review, a roadmap, and implementation [3], [15]. The positioning phase aims to examine the digitalization status of the whole target organization and provide a backlog of ideas and visions—what the organization identifies as development items. Therefore, this phase can also be characterized as the digitalization status analysis phase. After the positioning phase, the selected digitalization vision(s) is examined in more detail in the current state review phase to understand more deeply how current processes and tools work in relation to it. Based on this, a solution concept is designed for the selected digitalization vision. The roadmap phase aims to plan the steps for achieving the concept defined in the current state review phase. The implementation phase realizes the steps defined in the roadmap phase.

The model has been equipped with practical tools and a process that enables SMEs to carry out each step. A crucial part of the model is the positioning phase. It forms the basis for companies' digitalization improvement work since it intends to understand the current status of digitalization in the target company and identify improvement ideas. Therefore, we have focused the support service on making this assessment as easy as possible [15].

The method for the positioning phase contains three tools (Figure 1) [15]. This toolset has been released as part of the ApuaDigiin online service. The first step of the positioning phase is to determine the organization's digital maturity using the digital maturity tool. The tool is a free-of-charge digitalization self-assessment tool for organizations to assess their current digital maturity level [46], [48]. It is organized under six dimensions: strategy, business model, customer interface, organization and processes, people and culture, and information technology. Therefore, it measures the digitalization status of an organization from a broad perspective, not only from its technological aspects. After the most suitable option is selected from the answers presented, the tool calculates the maturity level value (from 0 to 4) for each dimension [46], [48]. The tool then presents a diagram (radar chart) that shows where the company stands in digitalization and where it is compared to the average of other respondents [49]. This analysis already provides valuable information to the company, but further analysis is required to identify potential improvement actions [15].

Fig. 1. Digitalization status analysis tools in the positioning phase [15]

The second step of the positioning phase is a SWOT analysis to identify and assess a company's digitalization strengths, weaknesses, threats, and opportunities. This is done with the DigiSWOT tool (see Appendix A), which is based on the SWOT template and contains instructions on applying it. An organization should consider how its digitalization strengths can be utilized better, how its weaknesses can be turned into strengths, and how opportunities can be seized and threats avoided.

The third step of the positioning phase is to collect ideas for digitalization improvement from the previous phases, further elaborate them, and collect them into the DigiTriangle tool (see Appendix B). The tool is used to classify the digitalization vision priorities of a company. The tool's structure divides the digitalization visions into three areas [3]: internal efficiency, external opportunities, and disruptive change. This tool is used to collect digitalization ideas into one frame, indicating their focus based on whether the ideas relate to the following:

- Improvement of internal efficiency, such as the deployment of a new IT solution to streamline internal processes;
- Improvement of external opportunities, such as offering existing services in a new digital way for customers; or
- Radical digitalization that can enable entirely new business for an organization or new partnerships or lead to an entirely new role for the organization in the value network.

DigiTriangle helps the company structure and present digitalization visions. Also, visions should be marked, if possible, as being short-term in a way that could be practical and concrete. In contrast, others may be long-term, such that they are generic development ideas that will be specified in more detail in the future.

3.2 Usage scenarios for positioning phase tools

Based on the experiences, we identified three usage scenarios (Figure 2) for the positioning phase method and tools. In the first scenario, SMEs use tools on their own to identify their state of digitalization and development path. This usage scenario has proven challenging because using the tools was not as easy as initially assumed. In particular, the use of the DigiMaturity tool turned out to be challenging for micro-sized enterprises [49]. In addition, smaller companies want to discuss their digitalization opportunities with an external operator. This was supported by our previous research, which indicated that smaller companies find it useful to discuss digitalization with an external person to gain understanding and new insights into digitalization [15].

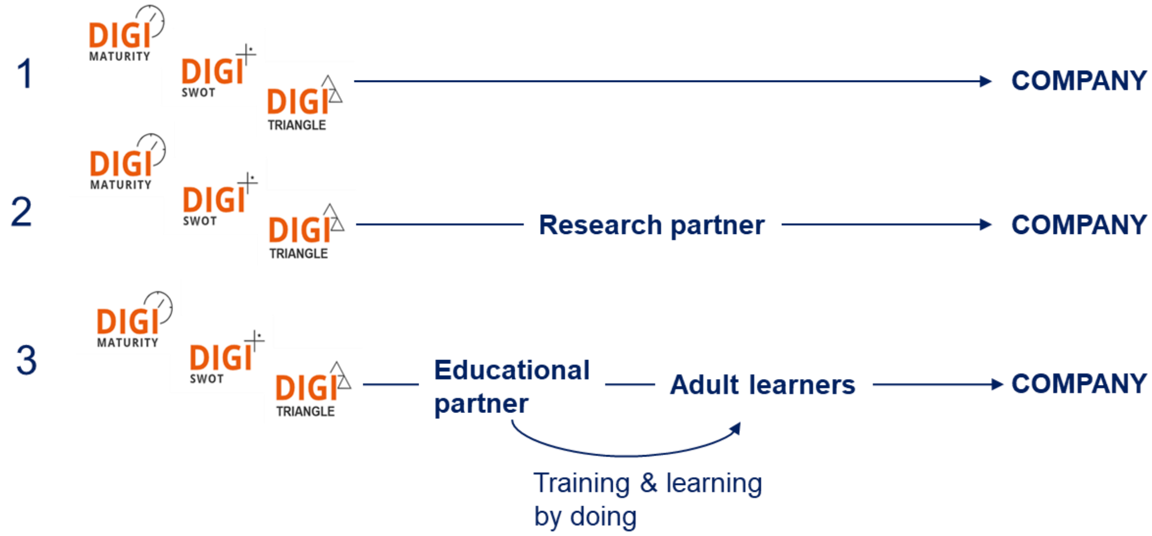

Fig. 2. Different usage scenarios of the digitalization status analysis

The second usage scenario relates to a situation whereby a researcher or other public sector actor is involved as an intermediary in helping an SME to use the tools and form interpretations of their digitalization results, providing insight into the potential of digitalization (Figure 3). This scenario was successfully tested and documented by Kääriäinen et al. [15]. The article describes how the research institute of the ApuaDigiin network helped 19 SMEs in the positioning phase of their digital transformation by using digital status analysis tools and methods, namely DigiMaturity, DigiSWOT, and DigiTriangle tools. Furthermore, the research institute continued with nine companies by coaching them through the subsequent phases of DT, namely current state review, road mapping, and implementation. The detailed experiences of the positioning phase effort have been analyzed and reported by Kääriäinen et al. [15]. However, in this scenario, the “intermediary” should have a strong understanding of the tools and digitalization to facilitate and support its assessment and finding improvement paths. In our case, the support work was done by a research institute that had been developing the service itself. Thus, it was already well acquainted with the tools and their application, which probably affected its success.

The problem with the second scenario is that the competence to conduct an analysis in the future does not permeate the company to enable it to analyze its future digitalization state. Nor will the second model develop new experts in digitalization status analysis and improvement for companies. Therefore, the third usage scenario relates to the idea of a trained “digital evangelist” and is inspired by the research literature. In this scenario, adult learners already working in organizations are trained to apply ApuaDigiin methods and tools as part of the training program. The group of students then assesses one organization’s digitalization (one student’s home organization) as a team. This way, so-called digital evangelists can be trained for the systematic development of digitalization. In the first two scenarios, this objective is difficult to achieve since the use of a practical research-based model and tools, as well as an understanding of digitalization, will not permeate into the company.

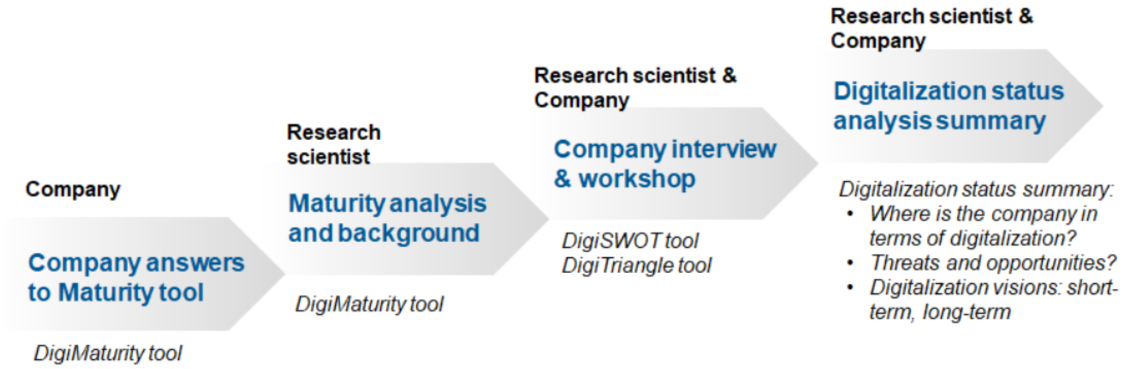

Fig. 3. The second usage scenario [15]

In this article, we present a study in which the digital evangelist approach has been applied to facilitate organizations' digitalization, focusing on the digitalization status analysis phase.

3.3 Research setting for testing the digital evangelist approach

This section presents the research method and question and explains how the research data have been collected and analyzed.

3.3.1 Research method and question

In this study, we adopt action research, allowing the researcher to engage with the training course students actively. Action research aims at transformative change through the simultaneous process of taking action and conducting research. Participatory action research (PAR) integrates research and action as a means to include the collection of data on the topic of investigation, analysis, and interpretation, as well as the planning and identification of action strategies to create positive changes [50]. The main idea of PAR is for research and action to be conducted with and for people rather than by experimenting on people [51]. Because of its approach, PAR enables the integration of research and practice so that the research informs and enhances practice and vice versa. Therefore, PAR differs from a case study approach, in which the researcher only acts as an observer of the studied subject or organization but does not engage in changing them [52].

The master's degree–level course entitled Leading in Digitalized Service Business at Lapland University of Applied Sciences in Finland aims to promote digitalization development in organizations. The goals of the course are such that after it, students will be able to analyze, evaluate, develop, and manage digital service businesses. All course participants have professional experience, and some already have experience in digitalization and its development in organizations. All higher education courses in Finland apply European Qualifications Framework (EQF) level 7 competence requirements [53]. Thus, the aim of studies leading to a master's degree is for graduates to have extensive and in-depth knowledge and the necessary theoretical knowledge to develop their careers in demanding specialist and management positions.

Furthermore, the aim is for students to have an in-depth picture of their professional field, its role in their professional life, and its social significance, as well as the ability to monitor and specify the development of research information and professional practice in the field. This is done at the course level by providing a theoretical knowledge base through lessons and students' individual research, as assigned during the course. Previously in the Leading in Digitalized Service Business course, there were lessons and an assignment whereby students familiarized themselves with VTT's DigiMaturity tool [48]. After this, they wrote an essay utilizing the latest theories and research articles concerning the six dimensions of the DigiMaturity tool from their viewpoint or that of a selected company. The approach of the course was more theoretical than solution-oriented. The goal of the EQF7 level is for students to gain competence to develop their careers in demanding specialist and management positions. Therefore, Lapland University of Applied Science decided to include group work on practical digitalization status analysis in the course to enable students to achieve the required competences better.

Our practical aim was to provide students with the ability to analyze organizations’ digitalization status systematically. We guided them to apply the method and tools of the positioning phase to carry out digitalization status analysis in target companies. From a research point of view, we were especially interested in studying the following question: how do the method and tools of the positioning phase of the DT model support the activities of a digital evangelist in a company? As described in the previous section, we refer to the digital evangelist approach as engaging intermediates trained to understand digitalization in companies and help those companies get started on improving digitalization.

The total number of students in the course was 31. The course started in September 2021 and ended in November 2021. Lectures provided students with an understanding of digitalization and digital business. The course included group work in which 11 groups of two or three students analyzed the digitalization status of one organization. Each group selected an organization to which one member belonged and analyzed its digitalization status (Figure 4). The groups then defined in more detail the unit of their target organization analysis (e.g., one department or whole organization). The unit of analysis was small (< 50 employees) in five groups, medium (> 50 and < 250 employees) in two groups, and large (> 250 employees) in four groups. Before the group work, the students were trained to use the digitalization status analysis method and tools.

Group ID		#1		#2		#3		#4		#5		#6		#7		#8		#9		#10		#11		In Total	
Domain		Mining /IT		Insurance		Energy		Consulting		Education /applied studies		Forest		Health services		Trade		Education /early childhood		IT		Education /vocational			
Organization (O) **T**argeted unit (T)		O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T
Size of O/T	> 250	x		x						x	x	x		x		x	x	x	x			x	x	8	4
	< 250 > 50		x			x							x							x				2	2
	< 50				x		x	x	x						x						x			1	5

Fig. 4. The characterization of the target organizations

3.3.2 Data collection and analysis

The research data comprised observations and notes from a results and feedback event, the groups’ digitalization status analysis reports, and questionnaire responses. One researcher worked as a lecturer for the course and collected feedback for research purposes. This person was responsible for teaching the use of the method and tools. In addition, the person answered students’ questions about using the tools and tried to ensure that they were understood and used correctly. The researcher also participated in the results and feedback event, where students presented the results of the digitalization status analyses they had completed for the target organizations. Each group compiled digitalization status analysis reports of their work comprising: a description of the target organization, how the tools were utilized, the analyses conducted, and the analysis report itself (showing the status of digitalization at the target organization and the improvement proposals). Observations from the results and feedback event were collected and documented as observation notes.

A questionnaire was also used to study the views of the course participants (see Appendix C). It aimed to determine how effective the method and tools were for the digitalization status analysis work and what kind of improvement proposals students identified related to the method and tools. The questionnaire was implemented with single-choice and Likert questions as well as open-ended questions using the Webropol tool. It was sent to the students (31 students) in November 2021. Answering the questionnaire was voluntary and anonymous.

All group reports were reviewed, and results and feedback session notes were interpreted to determine whether the method and tools were used and applied correctly and what kind of comments there were related to the method and tools. Additionally, the feedback from the questionnaire was analyzed. The research data from the questionnaire was transferred from the Webropol survey platform to Microsoft Excel. Thirty students answered the questionnaire. The material was then checked for errors, inconsistencies, and missing data. There were two single-choice background questions, two Likert-type questions related to the tools and method, and four open-ended questions. Open-ended questions resulted in a total of 53 free-text answers (90 lines of text). We used the descriptive technique [54] to analyze and describe quantitative data and content analysis [55] to analyze qualitative data. Two researchers analyzed the material from the open-ended questions by reading it several times and then categorizing it based on the respondents' interpretation of what worked well, challenges, and other observations.

4. Results

This research considers how the method and tools of the positioning phase of the DT model support the activities of a digital evangelist in a company in a setting in which adult learners carry out digitalization status analyses for a target organization.

The students produced digitalization status analysis reports of their group work. These reports were presented and discussed in a joint results and feedback session. The review of the group reports (digitalization status analysis reports) and observations from the results and feedback session supported the insight that all groups used the digitalization status analysis tools and workflow in an appropriate way. Principally, the groups also succeeded in identifying digitalization ideas and even divided them into short- and long-term ideas. The students saw the results and feedback session as an excellent opportunity to share their experiences with other groups and view practical example cases from different contexts.

The questionnaire seeking experiences and comments about the method and tools was sent to the 31 students, and 30 responses were received. Of the respondents, 27% indicated that they previously participated in developing their company's digitalization vision or strategy. The open-ended question asked how they were involved in this way. Most respondents said that their involvement had been in the form of making proposals for the digitalization of their organization. Subsequent questions were divided into two main sets: tools and the method. In addition, we asked respondents to describe what additional support or background information they would need to work as a digital evangelist at another company in the future.

We first look at how the students experienced using the digitalization status analysis tools. This was investigated using five Likert-scale statements and one open-ended question that enabled the students to comment on using the tools.

Figure 5 shows that over 70% (22) of the respondents felt that it was easy to select the appropriate answer from the DigiMaturity tool (Q1) and that the various answers had been discussed (Q2) in detail in groups. Discussion is essential for learning how to use the tool and what digitalization means in the different dimensions of the DigiMaturity tool in specific organizational contexts. Over 75% (23) of respondents indicated that the DigiSWOT tool was not difficult to fill in after the DigiMaturity tool was completed (Q3). Of the respondents, 60% (18) felt that it was easy to find digitalization improvement ideas, while ten (over 30%) responded neutrally, and two (~6.7%) felt that identification was difficult (Q4). Of the respondents, 60% (18) indicated that the components of DigiTriangle did not limit innovation in digi-ideas, while eight (over 26%) responded neutrally, and four (over 13%) responded that DigiTriangle limited innovation (Q5).

In the open-ended answers, the students considered the applicability of the tools for different situations. It was stated that the tools were suitable for small organizations. Nevertheless, when the company size is larger, it was found that limiting the analysis to a specific department or function and involving the right people in the organization was an essential approach for answering the DigiMaturity tool. This is understandable because as the size of an organization grows, understanding of its digitalization situation is scattered among different actors. This is related to understanding the tool's application in different situations, which is part of the digital evangelist's competence—the ability to understand how and where the tools can be applied in an organization.

> *Everyone related to [digitalization] improvement must be involved in the DigiMaturity tool analysis. It is also required to delimit the area or function of the organization to get the most out of the tools.*
>
> *The [DigiMaturity] tool provided food for thought and taught us to understand the need for a digitalization strategy. For some questions, we had to change our perspective from the previous question to find the right answer from an organizational perspective.*
>
> *The tool sparked ideas and helped to understand the digitalization state of the organization on a large scale.*

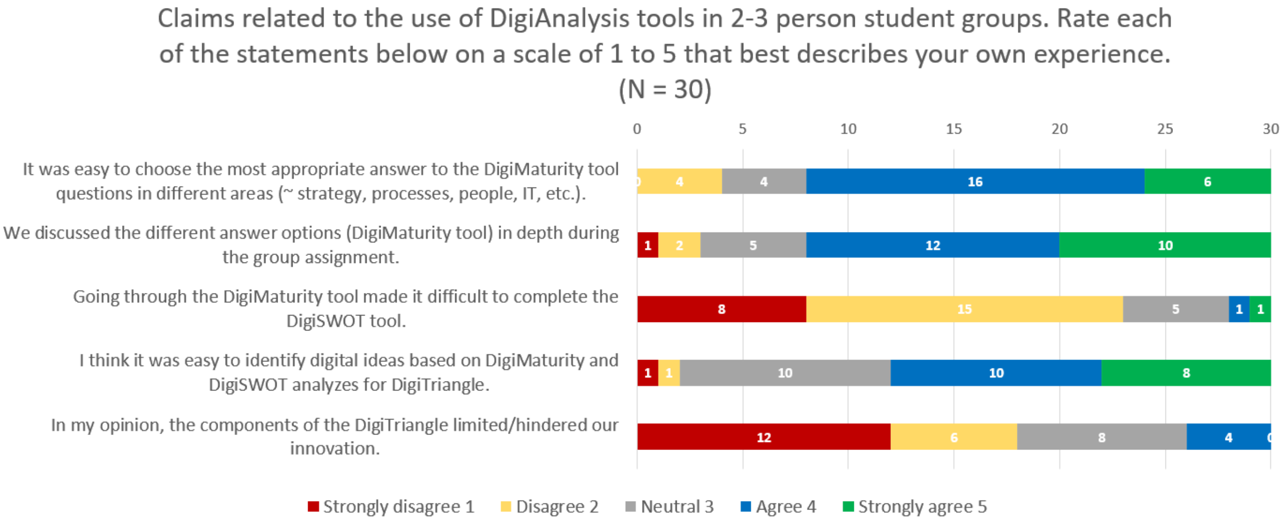

Fig. 5. Claims of the DigiAnalysis tools

However, some respondents found utilizing the tools to be challenging. For example, it was not easy to identify digitalization visions, although the respondents indicated that the tools had formed a logical step-by-step chain and facilitated this work.

> *At first, it felt like we were not getting external and disruptive digi-visions at all ... However, DigiMaturity helped with the SWOT analysis, and SWOT supported the making of the triangle. Yes, I will continue to use this tool.*
>
> *The DigiTriangle was the most challenging tool; staying at the SWOT level seemed easier.*
>
> *With the DigiMaturity tool, the transition from "level to level" was quite challenging to identify since the topics subject to assessment are pretty large and complex.*
>
> *The tools complemented each other in a logical order. DigiMaturity is extensive, and once it is done, you are pretty deep in the organization, and indeed it is easy to start looking for answers to the following tools.*

The students answered the claims related to the method (the tools' workflow) used in groups. This was also investigated with five Likert-scale statements and one open-ended question that enabled the students to comment on the method.

The method for digitalization status analysis presented in this article gave the students a better understanding of digitalization (Figure 6). The respondents felt that the method broadened their understanding of the concept (~85% (26); Q1), and they had gained the confidence that they could also apply the method at a new organization (~73% (22); Q5). Of the respondents, 60% (18) felt the method helped them understand the current status of digitalization in their target organization (Q2). Moreover, just over 50% (16) of respondents indicated that the method helped them generate digi-ideas (Q3). This relates to the challenges of identifying digitalization improvement ideas using tools (see the tools-related questions). Of the respondents, 50% (15) estimated that the results had been useful for their target organization (Q4). Seven (over 23%) were neutral responses, and over 25% (8) felt that the results were not useful for their target organization (Q4). Although, this is difficult to estimate since only one person in each group was an "insider" in the organization. In contrast, the others had to evaluate an organization that was unfamiliar to them.

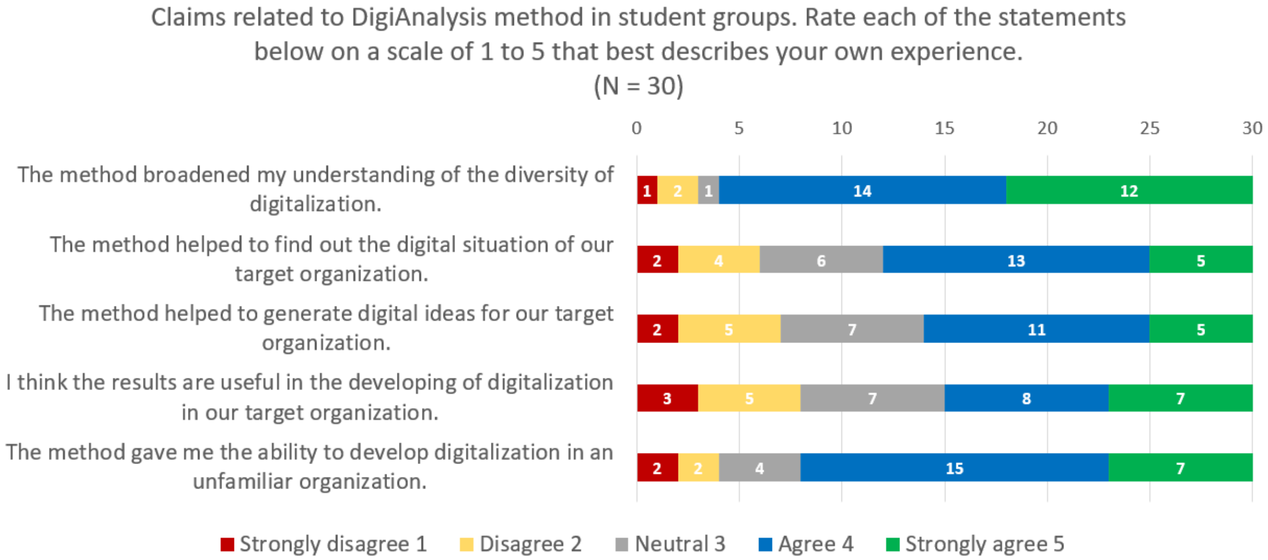

Fig. 6. Claims of the DigiAnalysis method

In the open-ended questions, it was identified as a challenge that only one person in each group knew the target organization well. Others found it more difficult to participate in the assessment. Nevertheless, several students also saw group work as positive since they could share ideas and discuss topics. The purpose of the course was for students to learn to operate in different situations, be an active part of a group, and be able to apply what had been learned. The results and feedback session broadened the students' views on digitalization, as they could hear the analyses made by other groups. The competence requirements at the EQF7 level require students to work independently, search for information, and apply theoretical knowledge in new operating environments. Still, based on the results, this seemed challenging for some.

> *The challenge was that one company was selected in the group that was familiar to only one student. Others found it challenging to participate in the analysis. It would have required significant initiative and interest from others.*

> *The working model made the group discuss the organization's digital solutions, from which one can also learn. At first, getting started was a bit sticky, but there was much discussion later.*

> *It was good to go through the topics together [the DigiMaturity tool]; it increased the discussion and different ideas on developing digital solutions in an organization.*

> *It was interesting to see and discuss [in the feedback session] how different organizations operate.*

Furthermore, we asked the respondents to describe what additional support or background information they would need to utilize the method and tools for future cases more effectively, even in an unfamiliar organization. For example, there was a need to understand better various digitalization and digitalization status analysis concepts, such as "disruptive change". Also, presenting practical example analysis cases would be beneficial for understanding the method and digitalization. It was also stated that the students needed knowledge about how to justify digitalization for companies; this would be something that could be used to influence people's attitudes toward digitalization. The comments also highlighted the importance of background information on the organization being evaluated and that the right group of people should participate in assessing the status of digitalization in the target organization.

> *I still need more reasoning and ideas for digitalization to cope with the attitude problems toward digitalization and understand why digitalization is worthwhile. In many cases, even those with attitude problems know that digitalization brings benefits, but more reasoning is still needed.*
>
> *Access to accurate input data [from the target company] is a critical area that must be available in order to be able to work as a digital evangelist.*
>
> *Getting started was a bit sticky, and the task assignment went too fast. Some practical example cases could give me an idea of how to proceed.*
>
> *Probably, I need more understanding of disruptive change, what it means in practice, etc.*
>
> *The introductory lecture could have opened up tools and defined more complex concepts. If I were a digital evangelist in a company, I would have to understand the [digitalization] concepts and tools that I present very profoundly, so I should have better background knowledge of them.*
>
> *The analysis requires time and multi-level reflection. It is worthwhile to conduct the reflection with a larger group [finding the right people] in a company, but with clear guidance. Finding out the company's background information, together with the staff, is essential.*

5. Discussion

This research considers how external support units can facilitate SME digitalization. This was studied by examining how the method and tools for the positioning phase of the digital transformation model support the activities of a digital evangelist in a company in a setting where adult learners are equipped to carry out digitalization status analyses in target organizations. The method and tools have already been used successfully in research organization–supported analysis for SME companies [15]. This article complements previous studies by analyzing how this method and its tools can be utilized in new usage scenarios where adult learners are trained to carry out digitalization status analyses in target organizations and thus learn through the learning-by-doing principle to apply the method in practice.

Our results show that the method of training digital evangelists to improve digitalization in companies was proven to work, at least in terms of analyzing the digitalization status and getting started with digitalization improvement. Practical support and guidance for the digital transformation journey of organizations were also emphasized by Zaoui and Souissi [23], Ulas [28], and Sándor and Gubán [41]. Barann et al. [16] stated that an important issue in this context, especially from the SME companies' point of view, is using a practical approach for companies and not abstract frameworks. Moreover, they highlighted the integration of external supporters to help in the digitalization pathway who would preferably be free-of-charge supporters. This is needed since SMEs do not have the resources to develop their digitalization [29]. Ulas [28] further called for support for SME digitalization, such as through customized training programs or support and coaching initiatives. In our approach, adult learners were trained to apply the digitalization status analysis method and tools as part of the digitalization course and carry out (free-of-charge) analysis in their home organizations. In the best case, when these students return to their home organizations, they can continue digitalization improvement work using free-of-charge tools. It is also good to note that the digitalization status analysis carried out as group coursework was done in a safe environment (lecturers and researchers guiding students) for students to learn and discuss how to use the method and tools and gain hands-on experience in digitalization.

Our results show that challenges were also encountered. For example, we interpreted that students' initial knowledge should be more comprehensive before they engage in practical analysis work. This requires the teaching of more comprehensive digitalization concepts as well as providing practical examples. Räisänen and Tuovinen [31] state in their research that entrepreneurs find opportunities for digitalization engaging, but the unique vocabulary in the ICT sector is not understood, and entrepreneurs would like to be shown concrete examples. To cope with this, they developed a workshop method that involved steps to clarify concepts, utilizing expert lectures and practical examples from other entrepreneurs to deliver peer learning. Ulas [28] advised SMEs to collaborate with SME helpers, innovation labs, and research institutions to guide them through current digitalization trends and demonstrate their importance based on practical examples (best-practice and real-life examples). It would also be useful for our approach, as the digitalization examples provided by business representatives are closer to the interest and experience of students already working in companies compared to research scientists providing examples. In practice, the course should be equipped with company case presentations, preferably presented by case company representatives. It would be relatively easy to achieve, as the target educational organization already uses recorded lectures (webinars) by the case companies in other courses; therefore, the operational model is familiar to the education organization. Also, analyzing digitalization in groups makes it possible for students to share their ideas and discuss them. However, this way of working requires students to have an active and participatory attitude; otherwise, they would not be able to participate sufficiently in the group work. Therefore, some adult learners must be encouraged to discuss group work actively. This should be highlighted at the beginning of the course since the competence requirements at the EQF7 level require this.

As discussed in Section 3, the method and tools used in this article result from long-term research and are part of the free ApuaDigiin web service and network. This service can be seen as a platform comprising methods, tools, and knowledge to support SME digitalization (Figure 7). This service incorporates external support units into digital transformation work to support SME digitalization efforts in practice. The network currently consists of educational partners, regional business development authors, research organizations, and associations (13 partner organizations in total) (Figure 7). There is already research evidence concerning publicly funded actor (research institute)–supported digitalization status analysis in this context [15]. On the other hand, the research reported in this article provides further empirical evidence of how educational partners can harness adult learners to carry out digitalization status analysis as part of their digitalization courses. In a broader scope, the ApuaDigiin approach also facilitates taking research results from universities and research institutes to support practical grass-root-level SME digitalization. It, therefore, contributes to the research impact and knowledge transfer from research to practical actions [12].

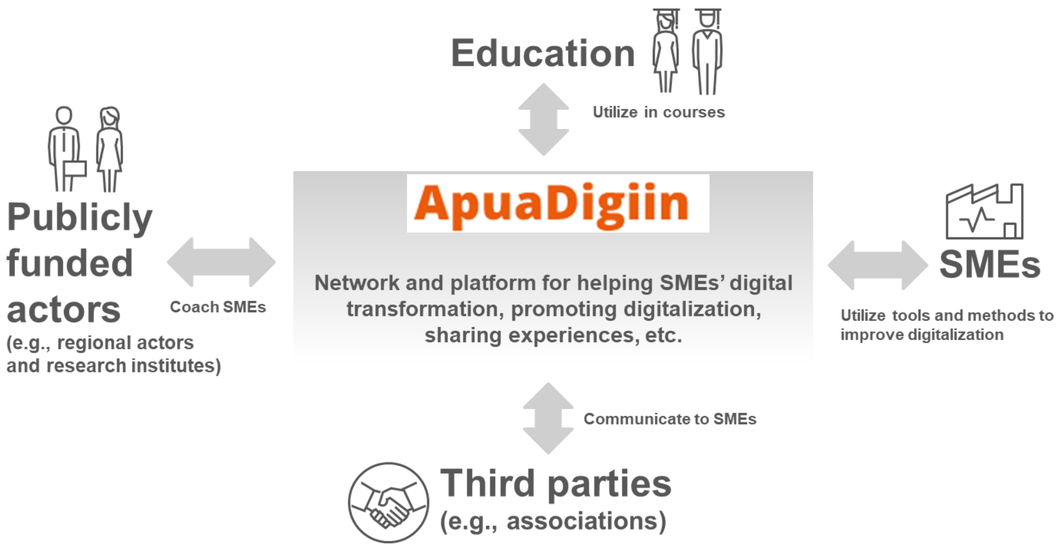

Fig. 7. ApuaDigiin network's stakeholders

6. Conclusion

This article contributes to the discussion of the digital transformation of SMEs and how publicly funded organizations can support it. The DT of SMEs is challenging since companies typically do not have the resources to advance it. Therefore, there has been a discussion on how public sector organizations can help in this. Our article examines how adult learners with professional experience can be trained as digital evangelists to facilitate the improvement of digitalization in companies. Our research sheds light on how digitalization status analysis can be supported as part of a course organized by an educational organization. The results show that the method and tools work in the context presented in this study. Based on these experiences, the proposed model and open tools may also be applied in other educational organizations to help teach new digitalization skills and perform practical digitalization status analysis in companies. Therefore, this study's findings benefit educational professionals interested in educating students to help SMEs along their digitalization pathway. This would promote how educational actors can support SME digitalization using open, free-of-charge tools and train adult learners to improve digitalization in their home organizations. The article also contributes to the discussion of how the research results of universities and research institutes can be transferred to practice. Moreover, the results will allow the positioning method and tools to be further developed and new user organizations to be included in the evolving ApuaDigiin open network to take advantage of the methods and tools available.

Limitations and future research

The results of the study cannot be interpreted without considering the limitations. Our study is based on eleven practical digitalization status analysis cases, of which seven were focused on SME organization units, and four were large organization units. This naturally limits the generalizability of our findings, and we need further experiments, especially in SME companies. It would also be interesting to study micro-sized companies since their digitalization has proven problematic [49]. Moreover, our research did not follow the DT process onwards to collect evidence on which digitalization ideas will be implemented in the case organizations in the future. This would require a longitudinal study and long-term access to case organizations, but it would be a fascinating future research topic. Finally, future practical improvement practices of ApuaDigiin should consider the systematics of how new research-based methods and tools can be incorporated into its service catalog, as was also stated by Sassanelli et al. [37] in their study, by referring to the concept of a service pipeline.

Acknowledgments

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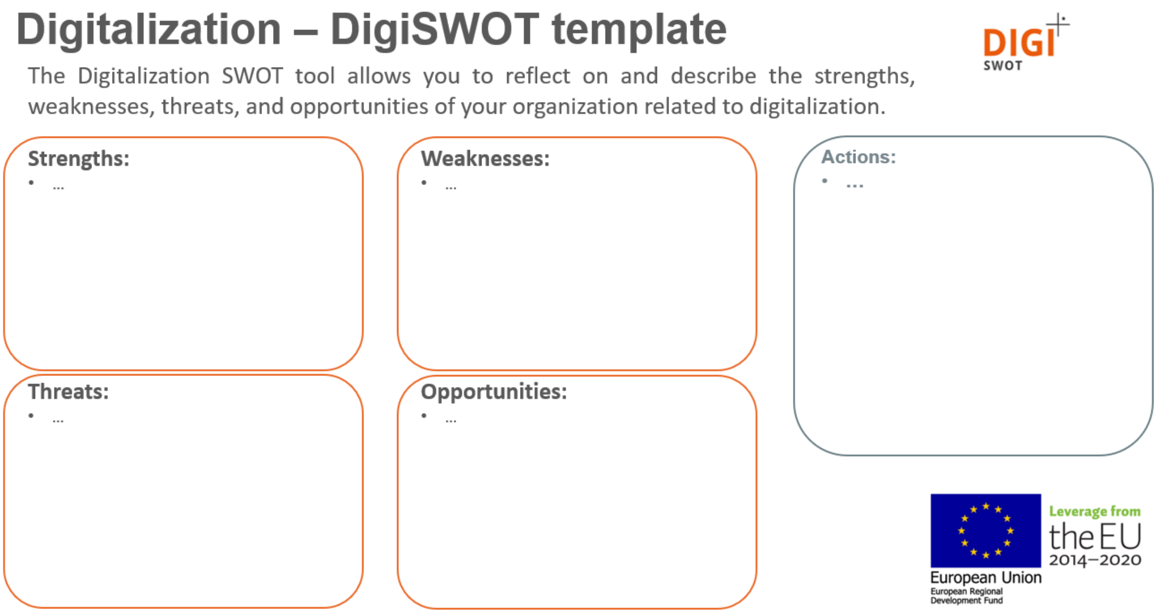
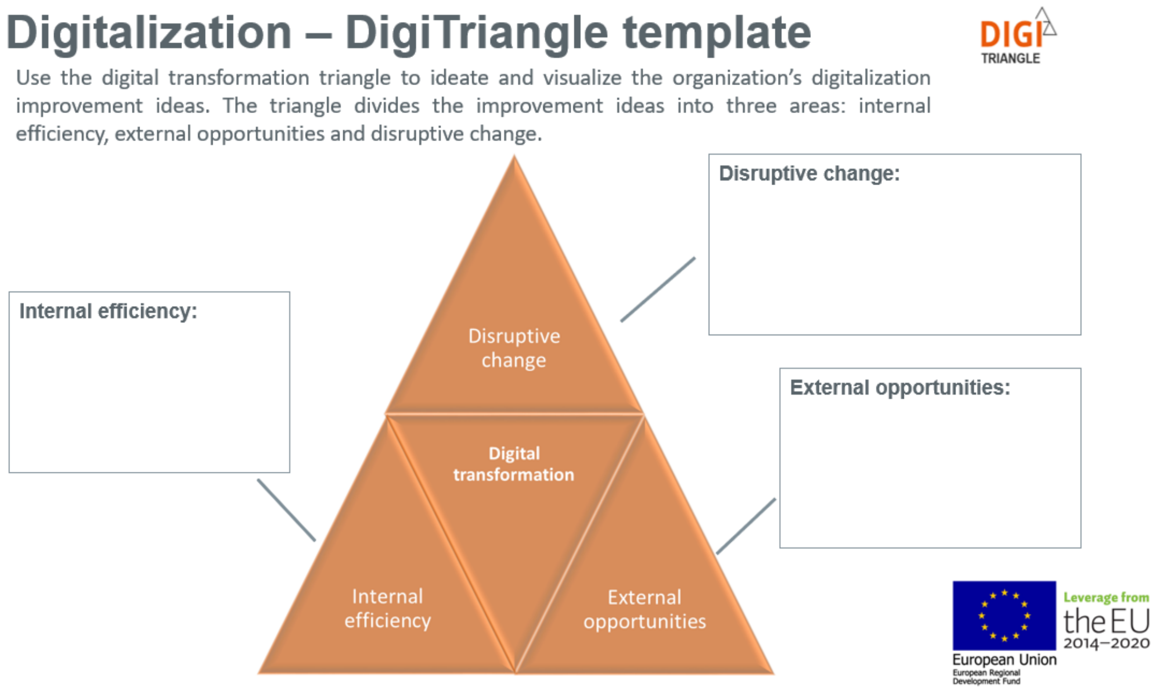
Appendix A. DigiSWOT template



Appendix B. DigiTriangle template



Guidelines - DigiTriangle

Use the digital transformation triangle to ideate and visualize the organization's digitalization improvement ideas. Write digitalization ideas in the boxes of DigiTriangle. Save the document containing your digitalization ideas to yourself. There are three categories in the DigiTriangle. Assemble your ideas into them and further consider the time perspective for implementing the ideas—what are the short-term and long-term ideas?

- *Internal efficiency:* describe digitalization ideas related to improving the company's internal efficiency—for example, new IT solutions to streamline internal processes or creating an IT roadmap.

- *External opportunities:* describe digitalization ideas related to the company's external capabilities when operating with customers or partners—for example, new digital service ideas for customers, existing services offered digitally, the development of e-marketing or IT solutions for exchanging information with partners.

- *Disruptive change:* describe the radical digitalization ideas of your company that can enable a new kind of business for the company, new partnerships, or even lead to an entirely new role for the company in the value network.

Leverage from the EU 2014–2020
European Union
European Regional Development Fund

Appendix C. Questionnaire template

Dear recipient,

We welcome you to answer the survey, with which we will gather your experiences and thoughts on how the DigiAnalysis tools (DigiMaturity, DigiSWOT, DigiTriangle) and method used in the course and group work performed in regards to achieving the course's competence goals.

Answering this questionnaire is voluntary and anonymous. All responses will be treated as anonymous and confidential. All data will be stored securely, and all answers will be treated confidentially. The data will be analyzed using qualitative and quantitative research methods so that individual answers cannot be identified.

1. Have you previously (before the course) participated in drafting the company's digital visions or developing the digitalization strategy?

   ○ Yes

   ○ No

2. If you answered "Yes" above, describe what you have done in more detail.

3. What is the size of the target organization you selected?

   ○ Small (1–50 employees)

   ○ Medium (51–250 employees)

   ○ Large (over 250 employees)

4. Claims related to the use of DigiAnalysis tools (DigiMaturity, DigiSWOT, and DigiTriangle) in two to three -person student groups:

Please, rate each of the statements below on a scale of 1 to 5 that best describes your experience.

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

Claims	**1**	**2**	**3**	**4**	**5**
It was easy to choose the most appropriate answer to the DigiMaturity tool questions in different areas (~ strategy, processes, people, IT, etc.).					
We discussed the different answer options (DigiMaturity tool) in depth during the group assignment.					
Going through the DigiMaturity tool made it difficult to complete the DigiSWOT tool.					
I think it was easy to identify digital ideas based on DigiMaturity and DigiSWOT analyzes for DigiTriangle.					
In my opinion, the components of the DigiTriangle limited/hindered our innovation.					

5. Please, write below (freely and if you wish) your observations about using the tools.

6. Claims related to the DigiAnalysis method in two to three -person student groups.

Please, rate each of the statements below on a scale of 1 to 5 that best describes your experience.

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

Claims	**1**	**2**	**3**	**4**	**5**
The method broadened my understanding of the diversity of digitalization.					
The method helped to find out the digital situation of our target organization.					
The method helped to generate digital ideas for our target organization.					
I think the results are useful in the developing of digitalization in our target organization.					
The method gave me the ability to develop digitalization in an unfamiliar organization.					

7. Please, write below (freely and if you wish) your observations about the working process during the course (DigiAnalysis method).

8. Please, describe your opinions (freely) below. What kind of additional support or background information did you miss during the course that would enable you to better utilize the method and tools in another company in the future?

Biographical notes

Jukka Kääriäinen
Jukka Kääriäinen works as a senior scientist at VTT Technical Research Centre of Finland Ltd. He received his PhD degree in 2011 and Licentiate degree in 2007 in Information Processing Science from the University of Oulu, his MSc degree in 1999 in Information Processing Science from the University of Kuopio and BSc degree in 1994 in Industrial Engineering and Management from the Walter Ahlström Institute of Technology. He has over 20 years of experience with digitalization, configuration management and application lifecycle management. He worked as a project manager of the DigiLeap European Regional Development Fund (ERDF) project that piloted and published tools and methods for the digitalization of SME companies. The project published the ApuaDigiin digitalization support online service for SME companies. Currently he works as the coordinator of the online service. He has worked as a project manager or researcher in several Prime Minister's Office's analysis, assessment, and research activities -projects related to digitalization. Furthermore, he has worked as a project manager, work package manager or researcher in various national and European research projects - such as ITEA, ITEA2, Artemis, Business Finland, EU and European Regional Development Fund (ERDF) projects.

Leila Saari
Leila Saari received her MSc degree from the University of Oulu, Department of Information Processing Science 1993. Currently she is a senior researcher in the Cognitive Production Research Area at VTT. From January 2018 to June 2019, she acted as the facilitator of Analytics plus growth network, an alliance of Finnish data analytics, machine learning and AI companies. The network is part of one AI Digital Innovation Hub (DIH), SuperIoT. Currently she is the contact person for AI maturity and willing to talk with the companies and organizations that have assessed their AI maturity with our free on-line tool. In May 2019 she completed the AI diploma organized by Aalto University and Helsinki University. During 2019 she contributed to the DigiLeap project that piloted and published the tools and methods supporting the digitalization of SMEs at ApuaDigiin online service.

Maarit Tihinen
Maarit Tihinen works as a principal lecturer for the master's degree programs at Lapland University of Applied Sciences. She is responsible for the curriculums of Expert in Foresight and Development as well as Service Management in the Digital Era. In addition, Tihinen participates strongly in various RDI activities and she is a certified Project Manager (IPMA-C). Tihinen graduated in department of Mathematics from the University of Oulu in 1991 and received her PhD in 2014 in Information Processing Science from the University of Oulu, Finland. Tihinen has worked in several national and international research and customer projects, and written scientific publications for both international conferences and journals. Her research interest includes topics of education, foresight, management, digital transformation, the Industrial Internet, business ecosystems and models as well as sustainable development.

Sari Perätalo
Sari Perätalo works as a doctoral researcher for Martti Ahtisaari Institute in Oulu Business School. Her thesis is on smart city business models. Specifically, she is interested in business models, strategies, and ecosystems. In addition, she has worked in several national and international projects of digitalization since 2016, for example in DigiLeap project creating new tools for SME companies for digitalizing their services and developing their business models.

Timo Koivumäki
Dr. Timo Koivumäki is an associate professor of Business Analytics at Martti Ahtisaari Institute, Oulu Business School. Previously he has worked as a professor of digital service business in OBS and as a research professor of mobile business applications at VTT Technical Research Centre of Finland. Koivumäki has over 20 years of experience in digital business research. His research interests include business analytics, consumer behavior, and digital service business.

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Employees' perception of value-added activity increase of Robotic Process Automation with time and cost efficiency: a case study

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Abstract:
Implementation of Robotic Process Automation (RPA) is ubiquitous in the financial industry. However, the consequences are not clear enough in terms of strategic perspective. Drawing upon the theory of Task-Technology Fit, this study explores the emerging consequences with the exploratory sequential method. Data related to the time and cost of processes before and after the RPA implementation were collected and descriptively analyzed. Even though time and cost efficiency improvements occurred in 50 out of 54 of the processes, the results indicated no labor reduction after the RPA implementation and no cost reduction in some business units, contrary to reports in the literature. To investigate what happened to the human resource environment, we surveyed 106 employees who were affected by the implementation of RPA. No variance was found between the characteristics of the employees and the changes in the working environment. However, the descriptive results of the survey revealed that employees' perception of value-added activities increased. These results provided that considering RPA as a routine process without calculating the strategic value creates process-oriented transformation with a lack of time and cost-efficiency.

Keywords:
financial technologies; RPA (Robotic process automation); value-added activity; cost and time reduction; task-technology fit.

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1. Introduction

Efficiency and effectiveness are the main keywords for achieving sustainable development and competitive advantages in business environments. The elimination of unnecessary business processes and tasks is the main driver of efficiency and effectiveness. Thus, software-made robots are common in the financial industry to increase the productivity and efficiency of costs and labor [1]. A study related to Robotic Process Automation (RPA), conducted by Fortune Business Insights [2], claims that the global market size for robots might increase by $7.64 billion by 2028. Therefore, up to two-thirds of knowledge workers might be affected [3] and a noticeable switch in the distribution of responsibilities between labor and robots might occur. According to Scheppler and Weber [4], most European companies are planning to implement software robots in at least 10 of their processes. Even this statistical perspective would be enough to recognize the extensive disruption that RPA will produce in companies.

Software robots are intended to reduce routine tasks by automating the process and eliminating the jobs related to the tasks to intensify the decision-making results; this is called Robotic Process Automation [5], [6]. The RPA technology is based on the elimination of the repetitive environment to enhance the productivity of the business [7]. Banking and accounting industry leaders in particular are applying RPA projects to their business processes because of their risk aversion and regulation responsibilities [6].

Elimination of repetitive tasks and processes creates an expectation of a reduction in the number of laborers to achieve cost efficiency. Replacing employees with RPA, generating a prospect of reducing the need for human resources, or directing these resources to meet the other needs of businesses, is a common perception of technological disruption [1], [8], [9]. Likewise, when routine tasks in a company are automated, related employees’ focus is expected to move to higher value-added activities. Human resource capability evolves to have a diverse and strategic nature with a new role in companies that implement RPA in their processes [10]. Task and RPA interaction requires to fit each other in order to see elimination or reduction which is a critical predictor conclusion for time, cost, and value-added activities to gain strategic value. Therefore, task and RPA interaction were evaluated by applying the Task-Technology Fit (TTF) theory [11].

Limited empirical studies and a lack of theoretical perspectives with the contradictory approach to RPA and labor reduction in the previous gray literature [12] created a motivation to investigate the unknown consequences of the implementation of RPA by applying the exploratory sequential method in a case study. Most organizations are failing to decide what to automate [13]. To evaluate the choice of the automation for the business units, TTF theory will be used to understand business units' tasks – RPA relations in terms of time and cost parameters to clarify the strategic value of the practical implementation of RPA with the combination of theoretical perspective and practical experience. Therefore, our case study, first, aims to investigate the time efficiency, cost efficiency, and human resource reduction after the implementation of RPA to perform tasks from secondary data that were collected from different business units in a financial institution. Its other contribution later is to evaluate whether human resource efforts can be transferred to value-added activities in this financial institution by implementing a quantitative survey method in the case study environment. Thus, this exploratory sequential design study first contributes to understanding the consequences of RPA implementation by evaluating the time and cost efficiency results with a descriptive case study and then investigating this exploratory outcome with a survey study to understand value-added activities among the participants who are the members of the business units that RPA was implemented with the task-technology fit theoretical lenses to observe strategic value.

The remainder of this paper is organized as follows. Section 2 provides the theoretical background and research proposal, while Section 3 presents the research methodology. Section 4 provides the primary and secondary data analyses and results. The final section contains a discussion of the results and concluding remarks.

2. Theoretical background and research proposal

Companies consider that carrying out business tasks efficiently and effectively ensures productivity, sustainability, and competitiveness. Operational performance can be leveraged through process optimization by reducing waste and errors, relocating high-cost destinations to low-cost ones, and adopting IT technology and automation with robots [14]. Automation is a powerful tool to reach these goals and to close the gaps between them. Robots are the main figure in the achievement of automation and better performance [15]. Among them, software types of automation create RPA, which is used for tasks to enhance the ability to operate in different applications and systems. The RPA technology operates with structural data, with which it connects to enterprise applications that interact with users in a client–server framework. In addition, the RPA application is executed with scripts that automate the users' workflows through dashboard-type interfaces [16]. Thus, RPA's technical ability has the capacity to change the nature of work by reducing the time, cost, and features and future of the labor [17]. In addition, the TTF theory explains that a good fit between task and technology brings better performance [18]. Therefore, task and technology characteristics need to fit each other to succeed in an intended time and cost performance from RPA implementation. There is always an interaction between task, technology, and individual perspectives of TTF, thus in our study the business units` each task is assessed in terms of time and cost to analyze strategic performance [11]. Considering the complicated environment of digital transformation, the vast literature on RPA explains its time and cost-effectiveness. Adaption of TTF is to analyze the literature perspective with a theoretical lens. Our study also includes a value-added activity perspective inside the financial institution with RPA whether a fit provides any positive performance on other tasks.

2.1 Time and cost effectiveness of RPA

There are always routine tasks and processes that companies want to minimize and reduce. If the requirement of task and the functionalities of technology are not close enough, then to reach the purpose of TTF gets harder [11]. The result of the reduction and minimization of these tasks and processes through the application of RPA generates time retrenchment for companies. It is claimed that RPA decreases the time required for high-frequency tasks [6]. In particular, RPA can operate at all times of the day, providing businesses with flexibility and scalability. Automating or decreasing the steps involved leads to tasks being completed within minutes/seconds instead of several days [10]. Thus, time efficiency is the expected result of the implementation of automation [10] which claims to have achieved a 30% to 70% reduction in the process cycles, waiting time, response time, and time taken to handle the processes. The duration of not only general business processes but also IT-related developments can be reduced with the implementation of RPA [14]. A study showed that also having the cognitive capability of RPA by using historical data saved employees millions of times to complete higher value tasks in a German financial institution [39]. Therefore, it is valuable to study this literature's task-technology fit expectations related to time reduction with practical hard data to compare the manual operations with the RPA-implemented processes and tasks. Our study investigates the time necessary for the processes to complete the specific tasks with RPA and without RPA and compares them to understand the fit between task and technology, leading to the following proposal:

> P1: The implementation of RPA reduces the time of the operation compared with the human resource who used to be responsible for that task, increasing the operational efficiency with the lens of TTF.

Cost reduction is a critical efficiency parameter for companies when they compare their performance. The majority of companies' operational cost is for the laborers who are employed to conduct the business processes. However, the adoption of automated systems enables a range of substitutions of labor in tasks. In particular, disruption occurs in the industry with the development of automated machinery [1]. Therefore, there is a high expectation of labor cost reduction when software-enabled automation is installed in companies. The past literature claims that the implementation of RPA tools also increases the product and service quality, which improves the operational performance with the elimination of human labor heavy tasks to robots while reducing the labor cost [1], [19], [20], [40].

A recent study by the World Economic Forum shows the transformation of tasks performed by humans to ones performed by machines, which shows to reduce the labor cost as well [3]. Huang and Vasarhelyi's [6] study corroborates the cost reduction through labor, showing a significant decrease in working hours and time of operation among accountants after the implementation of RPA. Furthermore, a prior study indicates that replacing full-time employees with robots allows labor-related expenses to be cut [10]. Therefore, the greatest concern among employees is losing their job due to RPA's cost promises and flawless operations compared to humans [6], [9]. A previous study's evidence indicates that managerial labor faces job losses because of average wage changes as a result of RPA implementation [19]. The notable difference between physical and software robots is that physical robots aim to reduce blue-collar labor costs and software robots aim to decrease white-collar labor costs [15]. Conversely, the RPA investment cost is critical for companies that plan to adopt this technology. The profit needs to exceed the cost of investment in RPA to motivate companies to install it for their processes [21]. The cost of RPA implementation is asserted to be less than the labor cost; however, inefficient processes and tasks that contain errors increase the cost of development and investment in RPA [4], [20]. Thus, the extent to which a cost reduction is achieved with the RPA adoption compared with human labor is not clear because of the additional costs for the maintenance of the RPA system after its implementation. Even though the cost reduction and the effect on the number of employees who are carrying out the processes seem to be clear, the cost of human resources and the RPA investment cost need to be investigated, especially among the business units, to compare the costs before and after the RPA implementation in a financial environment. Therefore, we unveil this gap by comparing the cost of labor for each business unit with the cost of RPA for specific units and their processes to identify the inconsistencies and propose that:

> P2: The implementation of RPA increases the cost-saving advantages over human resources for each process by decreasing the number of employees in business units that adopt RPA with the lens of TTF.

Since the processes transferred to RPA are repetitive, manual, and routine processes, the execution of the processes by the personnel or the robot does not create any change in the outcome. Since the quality of the process outcome was the same in both cases, only time and cost effectiveness were compared.

2.2 Value-added activity and RPA

Personal skills, creativity, and productivity are the main components of the development and adoption of high technologies in companies. RPA is a rule-based system that automates routine tasks and cannot mimic the actions and behaviors performed by humans [15], [20]. Eliminating the repetitive processes from tasks can change human resource activities in business units. Procedural human resource activities are transformed into value-added activities. Value-added activities are expected to happen, focusing more on decision making, problem solving, and interpersonal skills after the implementation of RPA [10]. Value-added activity transformation for employees shows that RPA implementation does not cut the total employment rate in business units [1]. Nevertheless, RPA tools improve employees' conditions, allowing them to perform multiple tasks with developed skills and strategic views on business tasks [20]. Implementing different algorithms to the business processes reshape human and algorithm relations over time without replacing human work. It is possible having new relations restructure existing roles into more accurate implementation of the technology [22]. Skillful and technology-friendly employees contribute to the success of RPA with their attainment. Non-routine processes and tasks are new roles for employees that generate value-added activities in businesses after the deployment of RPA [10], [23], [24]. Non-routine tasks and their consequences surge, allowing an innovative approach that forms a new type of labor perspective that engages with RPA [25]. RPA's promise of cutting labor costs seems to involve different approaches. Displacement of jobs does not occur; instead, RPA implementation creates new tasks and job opportunities and improves different labor activities, which increase the labor demand [1]. According to TTF, it is expected that technology assists individuals to improve their value-added skills with a new task engagement [11].

Our study investigates the amount of investment cost savings achieved through the use of robots instead of humans in operational tasks. These savings can be qualified as real savings if there is a real decrease in the number of human resources. If there is no decrease in human resources, the question of what kind of work is undertaken with the additional time obtained as a result of RPA will arise. Thus, we investigate employees in the business units of the financial institution that have adopted RPA, whose role has switched to more value-added activities with the lens of TTF, leading to the following proposal with the model Figure 1.

> P3: Employees' value-added activities appear in companies that shift their labor from the routine processes in which RPA is implemented.

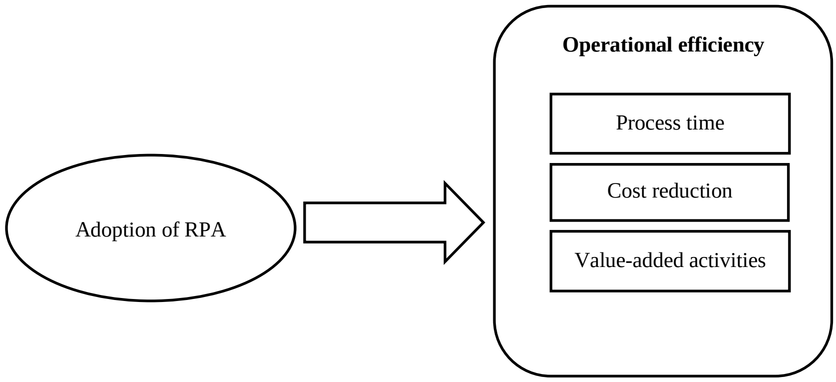

Figure 1: Model Proposal

These three models are tested separately and encompass all operational efficiency activities that RPA will add to an organization in the context of time, cost, and value-added activity increase in a single study.

3. Research methodology

The effects of the modeled RPA we created on time, cost and value-added activity are examined. The first two variables of these areas constitute the first part of the study, and the second variable is included as a continuation of the first analysis. These two sections proceed independently of each other, and the value-added activity section was included in the study by expanding the research, based on the fact that no real employee savings were observed as a result of the first analysis. Therefore, the survey analysis is the continuation and complement of the secondary data analysis as shown in Figure 2.

We applied an exploratory sequential approach in our study (Figure 2). First, a qualitative case study with a descriptive method was implemented by using secondary data. Second, a quantitative approach applied with survey design by using primary data. Secondary data analysis provided the necessary view to analyze primary data, and both were utilized to define the proposals with the theoretical lens of TTF. The following sections explain the secondary data collection and the survey settings with the primary data for our case study.

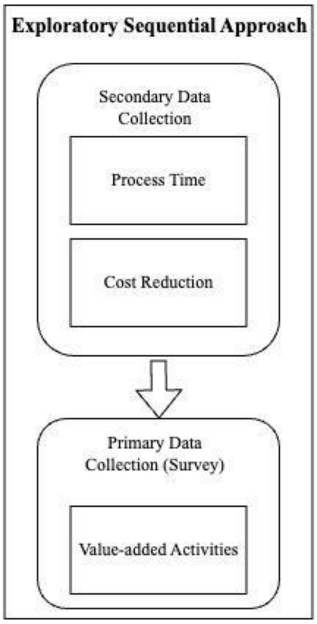

Figure 2: Data collection methodology

3.1 Secondary data collection

A comprehensive review of the RPA literature [4], [6], [7], [9], [10], [26], [27] directed us to choose time and cost data to answer the proposed research questions. We collected the data from a financial institution that operates in Turkey, as well as around the rest of the world. Its RPA implementation was chosen as a case for our study because it is the pioneer in the fintech industry related to RPA technologies.

While examining the gains from RPA, 54 processes in which the robot worked were considered over a 12-month period (May 2019–May 2020). These processes belong to 27 different sub-business services of seven different business units. With the transition to RPA, the changes in these processes were examined separately under the headings of time and cost to describe the conditions and the consequences in the financial industry.

3.1.1 Secondary data collection methodology for time

RPA implementation is expected to reduce the amount of time required for tasks to be completed. Therefore, the full-time employee (FTE) completion time for a specific process within a task is compared with the implemented RPA time frame that is used for the same process [24]. In line with this method, while calculating the gain in the time dimension, we calculated the number of seconds that an employee took to perform the same process on average in the year before the RPA was applied. The information systems used by the financial institution calculate the time elapsed between the assignment of each task to the personnel and the completion of the task. In this respect, the information of how long the tasks are completed by the personnel is an information that is automatically calculated by the system. Secondly, the average robotic time was found by calculating the average processing time of the robot per process. As a feature of the RPA product used, the information on how long it takes the robots to complete each task is data that is automatically calculated and reported by the system. Finally, the robot's time savings were compared on a business unit basis to analyze the differences in the processes of the units.

3.1.2 Secondary data collection methodology for costs

Similar to the methods reported in the literature, the investment in RPA, number of employees, and turnover rate calculations were applied to measure employees' procedures to investigate the cost reduction related to the labor in our secondary data collection from a financial institution [19].

The return on investment (ROI) is the main calculation to determine whether the investment benefits a company by reducing the costs. It is projected to improve efficiency because the ROI is better when RPA is implemented in processes, according to the literature [26]. The improvement is explained by the enhancement of productivity with the low-cost operation of robots compared with human resources [17]. Cost savings were not computed by Yetiz et al. [9] study, and no calculation method was defined to reach the cost-saving conclusion. Therefore, all the conclusions were speculations made by the authors. In addition, the RPA ROI perspective was compromised while explaining the cost savings in the paper. The main distinction in our approach is that we consider the RPA ROI perspective with the labor cost, which enables us to analyze the savings from the investment more realistically.

In calculating the cost savings obtained with RPA, the total cost for robotic investment and the human resource cost that would be spent if this development was not undertaken were compared. For the 54 processes in which RPA was implemented, the processing time of the employees (PTE) in hours to perform each transaction was calculated, and then the total time spent (TTS) by employees on these transactions was found by multiplying the PTE by the number of transactions (NoT).

$$TTS = PTE * NoT \tag{1}$$

The average daily effective working time of an employee in this workplace is 6.5 hours, according to the research made by the human resources (HR) of the financial institution. Using this figure, it was determined how many FTEs correspond to the total time spent by the employees on the transactions transferred to the robot. With the transition to the robotic process, the employee time spent on that process completely disappears, so the number of employees corresponding to the total time spent annually is saved.

$$FTE\ Saving = TTS/6.5 \tag{2}$$

FTE Saving is the number of employees needed to perform the same number of transactions in the scenario in which RPA has not been implemented. Therefore, FTE Saving was multiplied by the average human resource cost (AHRC) in each work group to calculate the total cost of an employee (TCE) in the scenario in which no robotic development was undertaken.

$$TCE = (FTE\ Saving) * AHRC \tag{3}$$

Some important aspects should not be overlooked in the cost calculation of robotic process automation investment. First, the employment of a team of robotic experts, separate from the relevant business units, for coding robotic processes stands out as an additional cost. In each case of robotic process development, it is necessary to calculate how many person days the central RPA team spends and the effort that this team exerts in following the process, updating it, and eliminating the related errors during the period after the related process is transferred to the robot. A more realistic approach is to include in the calculation the time required for the RPA team to be trained to code the process and the cost of the time that the RPA team spends without process coding because it is not working at full capacity. In the analysis method, the cost of the RPA team, the time spent writing the code, and the total cost of the time spent on all the above monitoring and control activities are included in the calculation.

Second, since the robots do not work at full capacity, when calculating the robotic cost (RC) for each business unit, a value should be obtained by dividing the total robotic investment cost (TRIC) by the total active working time (WT).

$$RC = \frac{TRIC}{WT} \tag{4}$$

This means that the cost of robots’ downtime is distributed to active robotic processes. For example, the capacity utilization rate of robots never exceeded 40% in the period examined within the scope of this study. Although full capacity operation was never targeted in terms of business continuity in robotic process automation, it can be said that 40% is a very low rate. In this sense, it may seem unfair that the total cost of robots with the ability to work 24/7 is charged only to the time that they work actively. On the other hand, no matter how inefficiently they are used, considering that all the robotic investment costs made by the financial institution in the analyzed period are for activated robotic processes, the method used is viewed as more realistic.

Finally, the cost reduction obtained by comparing the robotic cost (RC) and the total cost of employees (TCE) for each business unit is examined. The number of processes transferred to robots in each business unit to achieve the cost reduction is different. In this respect, the cost reduction per process is obtained by dividing the savings by the number of processes.

3.2 Primary data collection and survey measurement

3.2.1 Survey setting and data collection

The data were collected through an online survey tool that was designed in Google Forms. The survey link was shared through e-mail circulation with the employees who are affected by RPA and work in the treasury, human resources, legal affairs, risk follow-up, call center, operations, financial affairs, and marketing business units in the chosen financial institution. To establish content validity, in-depth interviews were held with executive managers who work at similar financial institutions. Likewise, the questionnaires were discussed with several academics in the field of financial technologies and revised based on the feedback. Eventually, clear, understandable, and well-structured survey questions were developed. The targeted respondents who would complete the surveys were the affected employees and the managers in the units in which RPA was implemented.

The survey questionnaire was originally prepared in English, then the final version was translated to Turkish. The survey was back translated to English to increase the accuracy of the questions. The translated English text was controlled by several academics again to preserve the original meaning of the survey questions for the study. Approval was obtained from the university’s research ethics committee before the dissemination of the survey. We randomly sampled 200 respondents throughout the units of the institution who are affected by the RPA implementation. A total of 106 questionnaires were returned. All the responses were usable, and the response rate was 53%. The business units are organized into four groups according to their process characteristics. A summary of the characteristics of the sample is presented in Table 1.

Table 1. Characteristics of the sample

Characteristics		**N=106**	**%**
Respondent’s position	Business unit employee	77	72.6
	Business unit manager	29	27.4
Work duration in the institution	< 5 years	40	37.7
	5 and > 5 years	66	62.3
Work experience	< 5 years	34	32.1
	5 and > 5 years	72	67.9
Business unit	Reporting-based processes (treasury, human resources, financial affairs)	28	26.4
	Operational processes (operation, risk monitoring)	50	47.2
	Call center processes	16	15.1
	Marketing processes	12	11.3

3.2.2 Measurement of the variables

In the survey, closed-ended questions and the Likert scale were used [28]. The survey was measured through a five-point Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree." The reason for using a five-point Likert scale is that it is less confusing than other scales and better quality responses are received from the respondents, according to the literature [29], [30].

Based on a comprehensive review of the relevant literature, the survey instrument was prepared to measure the employees' perception of value-added activity change after the implementation of RPA. During the literature review, we compiled our question sets based on the context of keywords such as "routine, repetitive, and manual work," "soft skills," "analytical work," and "job diversity," which are used in RPA articles that indicate value-added jobs after the implementation of robotic process automation. The survey questions that were asked to measure the rate of repetitive and manual work were adapted from earlier studies [17], [31], [32]. The questions examining soft skills after the implementation of RPA were also drawn from earlier studies [17], [33], and the questions regarding the necessity of technological capabilities before and after the implementation of robotic process automation were adapted from earlier studies [27], [31], [34]. All the questions that define Value-Added Activity (VAA) were combined into one set of questionnaires that constitutes the VAA construct.

4. Data analysis and results

In our descriptive case study, hard data were collected from the systems that belong to a Turkish financial institution, and the necessary calculation was performed to analyze the time and cost results. According to the results of hard data, primary data collected from the survey were also analyzed descriptively to explore the value-added activities of employees after the implementation of RPA.

4.1 Secondary data analysis and results for time

One of the most important added values of RPA is the increase in the transaction processing speed. Table 2 indicates that, in 50 of the 54 processes followed during the analysis period, the robot worked faster than an employee and performed the operations in an average of 63% less time.

Table 2. Results for processing time

Business unit	No. of processes	No. of processes in which the robot is faster	Average employee processing time (Sec.)	Average robot processing time (Sec.)	Average robot processing time efficiency
Treasury	7	7	2143	299	86%
Human resources	3	3	400	58	85%
Legal affairs and risk follow-up	3	3	160	40	75%
Call center	5	5	1392	424	70%
Operations	16	16	491	170	65%
Financial affairs	17	13	2241	831	63%
Marketing	3	3	68300	26533	61%
Grand Total	**54**	**50**	**5083**	**1870**	**63%**

Through a detailed analysis performed on a process basis, it is apparent that robotic time efficiency is higher in processes that currently have low automation rates and require the use of multiple screens. The more IT automation is done in the related processes, the easier it is for the personnel to perform that operation and the personnel processing time is reduced. Likewise, if there is a need to operate from more than one screen in the process, this slows down the personnel and causes a waste of time to switch between screens. When the robotic process is started, the transition between the relevant screens is much faster and the use of too many screens does not affect the robot as much as the personnel. This is the main reason for the robot achieving much greater time efficiency in the treasury and human resources business units. Conversely, it is evident that the time efficiency of robotic process automation is relatively low for operations processes, in which there are routine and very repetitive tasks, since the employees’ ability to perform these tasks is high. The high automation rate of the screens used by the employees because of the high level of IT capability is also a factor that affects the time efficiency in the operations business unit.

While the robot completed the process faster in 50 of the 54 processes in which RPA was applied, the robot was slower than the personnel in the following 4 processes belonging to the Financial Affairs business unit. These processes are presented in Table 3.

Table 3. Financial affairs business unit results for time

Business unit	**Process**	**Employee processing time (Sec.)**	**Robot processing time (Sec.)**
Financial affairs	Official reporting—daily public deposit—treasury	600	600
Financial affairs	Official reporting—spot foreign exchange—CBRT	900	1800
Financial affairs	Official reporting—TL101G CBRT	900	1800
Financial affairs	Official reporting—daily participation fund CBRT	1800	3600

The preparation time of the relevant reports by robots is equal to or longer than the preparation time by the employees. The main reason for this situation is that these reports are made with a very high degree of IT capability support when they are prepared by the employees. Although the IT improvements made on the screens where the employees make transactions do not fully automate the preparation of the relevant reports, they have facilitated the transactions by the personnel. With the transition to RPA, these IT improvements on the screens became useless and the previously spent IT resources were wasted. Therefore, some of the related IT support capability is lost when the robotic process is started, which may cause inefficient results.

4.2 Secondary data analysis and results for cost

While performing the cost comparison analysis, the 12-month total expenses covering the period of May 2020–May 2021 were considered and compared with the person–day cost to be spent in the scenario in which no RPA was undertaken. Thus, the aim was to achieve annual net cost savings with RPA.

One of the important expected outputs of RPA is employee savings. The full-time employee (FTE) savings field in Table 4 is the theoretical number of employees thought to have been saved in business units over the employee time eliminated. A total workload of 12.4 FTEs was transferred to robots. When the FTE savings per process with RPA are analyzed, the operations and call center areas are prominent. Savings of 6.8 FTEs were achieved in the operations business unit and 2.1 FTEs in the call center. Although the same workload savings were not achieved in all 27 sub-business units, it is apparent that an average workload of 0.5 FTEs is transferred to the robot in each sub-business unit.

The total cost of employees (TCE) in Table 5 is the total employee cost obtained due to not using manpower after RPA in the relevant processes. Conversely, during this period, it was observed that relevant processes were transferred to the robot by an average of 4.3 robotic process developers and an average of 5 robots. Table 5 shows the comparative results of these two costs.

Table 4. Employee savings

Business unit	No. of sub-business units	No. of processes	FTE savings	FTE savings per process	FTE savings per sub-business unit
Call center	2	5	2.1	0.4	1.0
Treasury	4	7	0.9	0.1	0.2
Legal affairs and risk follow-up	2	3	0.5	0.2	0.2
Human resources	1	3	0.5	0.2	0.5
Financial affairs	3	17	1.2	0.1	0.4
Operations	12	16	6.8	0.4	0.6
Marketing	3	3	0.5	0.2	0.2
Grand Total	**27**	**54**	**12.4**		

According to the analysis results shown in Table 5, savings of 1,145,004 Turkish lira (TL) can be made annually by switching to robots in 54 processes. The highest earnings were obtained in operations.

In the analysis of savings percentages, the highest savings efficiency was achieved in the treasury and human resources. It is apparent that the employee expenses in these business units were reduced by 81% and 73%. In contrast, the financial affairs business unit had the lowest savings rate, with 23% of employee expenses. The factors that caused the savings to differ for different business units are the annual number of transactions in the processes, the difference in the processing times of robots and employees, and the average human resource cost in those areas.

Even though financial affairs is the area in which the most processes are undertaken, it is evident that this business group ranks second from last in total savings. Therefore, the financial affairs unit ranks last in savings per process and savings percentages. Considering that the robotic development time is the same for all processes, the fact that the RPA team performs the most processes in the business unit with the least savings per process shows that it is not the right choice (Table 5).

Table 5. Results of the cost comparison

Business unit	No. of processes	Total cost of employees (TCE) (TL/Annual)	Robotic cost (RC) (TL/Annual)	Savings (TL/Annual)	Savings per process (TL)	% of savings
Operations	16	1,100,899	505,186	595,713	37,232	54%
Call center	5	337,342	155,655	181,687	36,337	54%
Treasury	7	188,595	35,307	153,288	21,898	81%
Human resources	3	86,275	22,936	63,339	21,113	73%
Legal affairs and risk follow-up	3	92,507	36,501	56,007	18,669	61%
Financial affairs	17	226,365	174,625	51,739	3,043	23%
Marketing	3	95,329	52,098	43,231	14,410	45%
Grand Total	**54**	**2,127,311**	**982,307**	**1,145,004**		

The main reason for the financial affairs and marketing business units appearing in the last place in both total savings and savings per process is their negative differentiation from other groups in the number of transactions per process (Table 6). Thus, the higher the number of transactions in the selected process during the analysis period, the greater the total savings from the process.

Table 6. Transactions per process

Business unit	No. of transaction	No. of processes	Transactions per process
Operations	441,682	16	27,605
Legal affairs and risk follow-up	17,130	3	5,710
Human resources	7,248	3	2,416
Call center	11,174	5	2,235
Treasury	7,478	7	1,068
Financial affairs	4,538	17	267
Marketing	74	3	25
Grand Total	**489,324**	**54**	**30,583**

Another reason for the low level of savings per process in financial affairs is that, in the above four processes (Table 7), in which the robot works more slowly than the employees, no savings could be obtained from robotic process automation and the RPA investment was lost.

Table 7. Financial affairs processes

Process	Robot annual cost	Employee annual cost	Annual net saving
Official reporting—daily public deposit—Treasury	7,351	4,892	-2,459
Official reporting—spot foreign exchange—CBRT	22,054	7,338	-14,715
Official reporting—TL101G CBRT	22,054	7,338	-14,715
Official reporting—daily participation fund CBRT	44,108	4,677	-29,431

The actual number of employees in all the business units was examined after RPA. It is remarkable that no real reduction in the total number of employees was achieved in any of the business units. One of the main reasons for this situation is that the workload savings is less than one person in all the business units except the call center (Table 8).

Even though the workload was transferred to robots, each unit kept its current employees, which posed a question about what happened to the effectiveness that was gained from the implementation of RPA. Thus, we investigated the employees' perception of value-added activities to explore the real cost-saving tendency related to the labor cost. The third part of our research investigated whether employees perceive that these savings are directed to VAA.

Table 8. Employee savings

Business unit	No. of employees before robotics	No. of employees after robotics	Real employee savings
Call center	23	23	0
Treasury	17	17	0
Legal affairs and risk follow-up	9	9	0
Human resources	12	12	0
Financial affairs	14	14	0
Operations	48	48	0
Marketing	18	18	0
Grand Total	**141**	**141**	**0**

4.3 Primary (survey) data analysis and results for Value-Added Activity (VAA)

The unchanged number of employees after the implementation of RPA captured our attention and directed us to investigate the value-added activity presence among employees to see how the efficiency and effectiveness of RPA appear in the financial institution. The quantitative survey results were analyzed with descriptive statistics to understand employees' perception of value-added activities within the business units in which they operate.

4.3.1 Measurement method and results

Our research proposal was to investigate value-added activity appearance in business units that had implemented RPA. We decided to perform a factor analysis of our sample and compare the differences according to the characteristics of the sample to determine how VAA changes accordingly. The first step was to conduct a factor analysis, forcing us to eliminate four questions out of 14 because of reliability issues and the internal consistency of the questions. A repeated factor analysis test with the remaining questions created one factor that explains 55.2% of the total variance and was defined as the VAA construct in line with the literature [1], [17], [35]. The reliability of the construct was measured with a Cronbach's alpha of 0.904, which is above the necessary threshold of 0.70 [36]. In addition, each question's factor loadings are above the accepted minimum level of 0.50, which ensures the content validity of the survey (Table 9).

A normality test is necessary to decide whether the samples are distributed normally and thus whether to choose a parametric test or a non-parametric test for the variance analysis. The skewness and kurtosis values were checked and shown to be between -1.5 and +1.5, which indicates that our sample is normally distributed [37]. Therefore, to test the variance analysis between the VAA construct and the characteristics of the sample, we decided to perform an independent t-test that includes two groups in the characteristics variables, respondent position, work duration at the institution, and work experience. A one-way ANOVA test was performed to measure business units' characteristic variable, which contains more than two groups — reporting-based, operational-based, call center, and marketing business units — to examine the variance between the VAA construct and the characteristics.

Table 9. Descriptive analysis of value-added activity (VAA)

	Items	Mean	Std Deviation	Variance	Factor loading	α
Value-added activities						**0.904**
After the implementation of Robotic Process Automation (RPA), the time allocated to manual and routine tasks/work performed by the employee decreased.	Q1	4.02	0.84	0.71	0.633	
After the implementation of Robotic Process Automation (RPA), creative work emerged.	Q2	3.62	0.86	0.75	0.793	
After the implementation of Robotic Process Automation (RPA), knowledge-based jobs increased.	Q3	3.48	1.00	1.01	0.651	
After the implementation of Robotic Process Automation (RPA), problem-solving skills are used effectively in the work.	Q4	3.69	0.84	0.70	0.789	
After the implementation of Robotic Process Automation (RPA), technological competence is required for the work.	Q5	3.81	1.03	1.06	0.647	
After the implementation of Robotic Process Automation (RPA), a proactive approach can be adopted in the work.	Q6	3.77	0.83	0.69	0.803	
After the implementation of Robotic Process Automation (RPA), employees can focus on the analytical side of the work.	Q7	3.85	0.92	0.84	0.805	
After the implementation of Robotic Process Automation (RPA), innovative approaches can be introduced into the work.	Q8	4.02	0.78	0.61	0.809	
After the implementation of Robotic Process Automation (RPA), job diversity increased.	Q9	3.34	1.04	1.08	0.739	
After the implementation of Robotic Process Automation (RPA), business processes in which decision-making skills are used increased.	Q10	3.54	1.00	1.01	0.724	

Notes: 5-point Likert scale: 1 (strongly disagree) to 5 (strongly agree); 〈 = Cronbach alpha.

4.3.2 Analysis results

The survey results show the variance between specific characteristics of the employees and their VAA in the business units in which robots currently operate. The t-test was conducted between the respondent position, the work duration at the institution, the work experience, and the VAA of employees. The results show that none of the characteristics' values of the two groups vary with the VAA of employees ($p > 0.05$). Thus, the VAA is not changed by the institution's specific characteristics. The business units of the institution, according to the ANOVA test results, are also not significant ($p > 0.05$), indicating that none of the business units' values make any difference to the VAA perspective among the employees with the implementation of RPA. These results explain that the VAA of the employees does not vary with the institution's measured characteristics. In addition, the descriptive statistics of the survey, presented in Table 10, indicate that RPA implementation helps the institution's business units only in the completion of routine tasks which fit with the technology.

Table 10. Descriptive statistics of the questionnaires

Survey questions	**Strongly disagree (1) %**	**Disagree (2) %**	**Neither agree nor disagree (3) %**	**Agree (4) %**	**Strongly agree (5) %**	**Mean**	**Std. deviation**
After the implementation of Robotic Process Automation (RPA), the time allocated to manual and routine tasks/work performed by the employee decreased.	1.9	4.7	8.5	**58.5**	**26.4**	**4.03**	0.84
After the implementation of Robotic Process Automation (RPA), creative work emerged.	0.9	11.3	**23.6**	**52.8**	11.3	**3.62**	0.86
After the implementation of Robotic Process Automation (RPA), knowledge-based jobs increased.	1.9	17.9	**24.5**	**41.5**	14.2	3.48	1.00
After the implementation of Robotic Process Automation (RPA), problem-solving skills are used effectively in the work.	0	10.4	**23.6**	**51.9**	14.2	**3.70**	0.84
After the implementation of Robotic Process Automation (RPA), technological competence is required for the work.	1.9	14.2	10.4	**48.1**	**25.5**	**3.81**	1.03
After the implementation Robotic Process Automation (RPA), a proactive approach can be adopted in the work.	0.9	7.5	**19.8**	**56.6**	15.1	**3.77**	0.83
After the implementation of Robotic Process Automation (RPA), employees can focus on the analytical side of the work.	1.9	9.4	10.4	**57.5**	**20.8**	**3.86**	0.92
After the implementation of Robotic Process Automation (RPA), innovative approaches can be introduced into the work.	1.9	2.8	9.4	**62.3**	**23.6**	**4.03**	0.78
After the implementation of Robotic Process Automation (RPA), job diversity increased.	1.9	**24.5**	23.6	**37.7**	12.3	3.34	1.04
After the implementation of Robotic Process Automation (RPA), business processes in which decision-making skills are used increased.	2.8	16	**17.9**	**50**	13.2	**3.55**	1.06

5. Discussion and conclusion

In the first part of the exploratory sequential approach of the study, secondary data collected from various units of a financial institution were used and the effects of RPA on time and cost efficiency were examined. In the second part, according to the information extracted from the initial descriptive case study, the effect of RPA on the VAA of employees was analyzed by interpreting the primary data obtained through the questionnaire, and it was determined whether the time and cost savings obtained from RPA allowed the related units' employees to focus more on value-added activities to see the strategic value.

The analysis of the secondary data showed that robots completed the process faster than employees in 93% of the processes (50 of 54 processes). When all the processes are considered, it is apparent that robots work on average 63% faster than humans, which supports the literature in general [6]. The use of multiple screens in RPA-applied processes, staff members' experience with screens, IT automation, and the business alignment rate came to the fore as the main factors affecting the relative speed of the robot compared with the staff. Therefore, a remarkable result is that, in four out of 17 processes in the financial affairs business unit, the robot works slower than the employees and the RPA application cannot be exploited in terms of speed; this result is not in line with the literature. According to the literature, while RPA should save time, it was observed that the robot did not work faster than the personnel in some of the processes examined. [6]. It is believed that robots are more efficient in routine work; therefore, the IT capacity and capability can be improved in business units that require a high level of knowledge, and transactions can be carried out faster. Also, it is possible that the tasks in the financial affairs business unit may have non-routine characteristics, thus the relationships between tasks and technology may construct a low fit presence to produce necessary strategic value related to timesaving [11].

The second analysis using secondary data focused on cost savings. The results show that a total of 12.4 full-time employee (FTE) jobs were transferred to the robot. When the number of processes transferred to the robot is evaluated, the units with the highest FTE savings per process were operations and the call center. As a result of the comparison of the total employee cost, which corresponds to the FTE savings obtained, and the cost of the robot, it can be seen that the financial institution has saved 1.1 million TL in a year. This amount of savings shows that cost efficiency of 54% has been achieved. The annual number of transactions in the relevant processes, the difference in the processing speed of the robot and the employees, and the average human resource cost are important factors explaining the differences in the amount of savings in business units. For example, although the financial affairs department is the unit where most processes are transferred to the robot, it ranks second from last in total savings and last in savings per process. This situation shows that financial institutions that implement RPA should make more rational choices to achieve the highest level of efficiency when choosing a process. This result supports that one of the most important challenges in the banking and financial industry is to select the right process to use RPA [41]. To achieve more rational choices in business process management at the beginning of RPA project, a combination of human intelligence, process mining by extracting event data from Information Systems, and artificial intelligence by generating a standard classification on deviated, failed, or delayed processes can be implemented to discover most logical business processes [13]. Since RPA deals with structured data, AI implementation with RPA would solve the gap in capturing unstructured data by having capabilities such as Optical Character Recognition (OCR) and Natural Language Processing (NLP). Transforming traditional RPA into Cognitive RPA with these technologies creates human-like capabilities that help to improve a better understanding of the processes of the organizations [39]. This way task-technology fit can be achieved. Also, RPA may create risk and weakness in a more controlled environment which needs to be addressed in the financial affairs department to align with TFF theoretical perspective [38].

One of the most striking results of the study, contrary to the literature [9], [10], [15], [19] is the fact that no real employee reduction was observed in any business unit, although 12.4 FTE of work was transferred to a robot through robotic process automation. This situation raises the question of whether the reduction in workload and time savings as a result of the RPA implementation in the relevant units led to an increase in value-added activities.

To answer this question, the integration of both qualitative and quantitative analysis in a descriptive case study was applied, and the primary data obtained through the survey were examined. The results reveal that there was no statistically significant difference between the views of the employees based on their position, work duration at the institution, and work experience. Conversely, when the questions with which the employee agreed most (evaluating the sum of the agree and strongly agree responses) were examined, it was apparent that the rate of employees who think that innovative approaches have increased in their work is 85.9%. In addition, it was observed that the rate of employees who believe that the analytical focus has increased is 78.3%, while the number of employees who think that there has been a decrease in routine and manual work is 84.9%. The subject on which the employees agree least is the thesis that job diversity has increased. While the rate of the employees' agreement with this opinion was 50%, the percentage of respondents expressing disagreement and strong disagreement was 26.4%.

In the 10 questions asked about the increase in value-added activities, the average agreement rate of the employees was 69.4%. This shows that the employees think that there has been an increase in value-added activities in the business unit in which they work since the RPA implementation. This result supports our last proposal and some of the literature related to employee effort in value-added activity [10], [17], [23], [24]. On the other hand, our results contradicted the studies that were evaluating RPA implementation in the public sector in which the employees were not focused on value-added activities without giving education [42]. This indicates that financial sector employees` capability on adaption of RPA and business analytical capability is high, but additional educational support could increase employees` innovative approaches. In the evaluations made based on the survey results, it is seen that the time allocated to develop the digital and analytical competencies of the employees and to obtain insights about the areas they are responsible for by using their business analytics competencies has increased. It is also seen that they interact more with other units and do more collaborative work and focus more on design-oriented product and process development activities for the development of business processes.

It can be concluded that the reason for the increase in job diversity is relatively low is that robots can only undertake routine work in the institution; therefore, the institution can benefit from RPA only within the framework of descriptive applications. In addition, the results indicate that the basic level of RPA implementation is not enough to capture necessary strategic output; instead the RPA implementation should be either cognitive or artificial intelligence level to eliminate the task-technology fit problems in some units [12]. When evaluating the institution in terms of process analytical capability, it is understood that it cannot switch to automatic decision-making mechanisms, which we can call full automation, which is the predictive level. Likewise, instead of focusing on directly the individual processes, RPA strategy needs to consider a holistic approach with customer-oriented solutions in financial institutions [39]. As a result, since it still needs human capital, real cost savings cannot be realized from the perspective of the number of employees. The result also revealed how task-technology fit impacts the performance of overall expected efficiency results with strategic value. Therefore, task and technology alignments are necessary to get the predictive level benefits of the RPA technology.

Limitations and future research directions

Although the fact that our study examined only one financial institution’s use case prevents us from generalizing the results to all financial institutions, in practice, this study suggests that similar companies should benefit from this experience and implement RPA for more routine processes. Another conclusion to be drawn for these companies is that the use of predictive data, the capabilities of which have been improved with AI, and the development of IT competencies in complex jobs can yield more successful results than RPA. The low number of processes transferred to robots in the financial institution is another major limitation of the study as it resulted in insufficient sampling. The study was carried out two years after the financial institution started the RPA application and only 54 of the 757 processes in the financial institution were included in the RPA application studies to be carried out in institutions where the maturity level of RPA implementation is higher will provide more efficient results in terms of a larger sample. Conversely, the fact that RPA has not yet been implemented in any process that requires optical character recognition (OCR) is the biggest obstacle to reaching higher levels of technological efficiency. OCR increases the potential number of processes that RPA can run effectively. In this respect, it is estimated that RPA can produce very effective results in studies to be carried out in organizations with a high level of OCR usage. The third limitation is that the RPA application does not contain artificial intelligence. The inability of RPA to be applied to processes that require artificial intelligence has caused many high-value-added processes with robotic potential to be excluded from the application. With the development of RPA applications with these features in the coming period, it is expected that time and cost efficiency will reach much higher levels and that the value-added activity increase will be at a much higher level in the units in which RPA is applied. Finally, the use of an employee questionnaire as a measurement method of the increase in value-added activities is also considered as a limitation. The lack of data on how much of the total time distribution of the employees in terms of workload is spent on value-added work resulted in the inability to make a statistical measurement in this regard. Test of the first and second proposals is quite reliable in that it is derived entirely from the financial institution's information system’s data. On the other hand, making the third proposal based on the bank's workforce distribution data rather than the personnel survey data will provide a much more reliable environment to validate the value-added activity increase thesis. The fact that the financial institution did not keep these data led to the necessity of testing the third thesis with the survey method. In future studies, analyzing the employees’ workload distribution before and after the RPA application, considering the nature of the job, will be a step toward overcoming this limitation. In addition, by measuring IT performance in the future, the performance difference between the processes in which IT automation is applied and the processes in which RPA is applied will provide a clearer perspective on the selection of applications.

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Towards a framework for developing visual analytics in supply chain environments

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Towards a framework for developing visual analytics in supply chain environments

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Abstract:
Visual Analytics (VA) has shown to be of significant importance for Supply Chain (SC) analytics. However, SC partners still have challenges incorporating it into their data-driven decision-making activities. A conceptual framework for the development and deployment of a VA system provides an abstract, platform-independent model for the whole process of VA, covering requirement specification, data collection and pre-processing, visualization recommendation, visualization specification and implementation, and evaluations. In this paper, we propose such a framework based on three main aspects: 1) Business view, 2) Asset view, and 3) Technology view. Each of these views covers a set of steps to facilitate the development and maintenance of the system in its context. The framework follows a consistent process structure that comprises activities, tasks, and people. The final output of the whole process is the VA as a deliverable. This facilitates the alignment of VA activities with business processes and decision-making activities. We presented the framework's applicability using an actual usage scenario and left the implementation of the system for future work.

Keywords:
visual analytics; supply chain analytics; conceptual framework; business intelligence.

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1. Introduction

Visual Analytics (VA) capability has shown to be of paramount importance for Supply Chain (SC) analytics. Nevertheless, SC stakeholders yet struggle to integrate it into their data-driven decision-making activities [1], [2]. In order to exploit the VA capability, there should be an alignment in a top-down approach from business strategies and their inferring business processes and issues, all the way down to decision goals and analytical tasks [3]. On the other hand, SC partners need to collaborate and share information throughout the chain to gain mutual benefits and leverage their data assets [4]. However, data sharing imposes numerous challenges, such as information leakage [5]. To mitigate such challenges, it is imperative to have a data governance framework in a consensus of various partners, without which data would not be utilized as an asset [6]. In general, many factors should be considered to have a well-established VA system. For instance, a VA system requires a human-in-the-loop process model to streamline human interaction with various stages of the process [6].

The study of developing VA into SC decision support systems is comprised of various aspects belonging to different disciplines. Within the information system community, several studies have explored the connection between user requirements and visualization practices [7], [8]. However, SC requirements are not explored significantly. At the same time, the Business Intelligence (BI) community is studying the mapping of business processes to specific analytical activities, but without identifying visualization best practices [9]. In general, business processes are considered but not supply chain-specific processes. VA community addressed many visualization aspects, such as automation, recommendation, and interaction [10]–[12]. Nevertheless, they are often generic, and decision areas that link the VA system with business decision goals are not identified rigorously. On the other hand, data governance has neither been explored regarding SC stakeholders' data challenges nor been explicitly considered for VA system requirements [13], [14]. Finally, although the SC community recognized VA as one of the SC data analytic capabilities, it is not discussed sufficiently [15].

In computer sciences, conceptual frameworks are the constellation of concepts, assumptions, expectations, processes, and methodologies that support the development and deployment of a technology in an application domain [16]. Therefore, conceptual frameworks can be used to understand a real-world phenomenon and to provide a roadmap toward streamlining the integration of a technology into its corresponding application domain. In SC VA, a conceptual framework can be used to understand the interlinked concepts from SC decision-making, data governance, VA requirements, and their relationships. It can also outline target decision areas, data sources, data sharing requirements, human agents, and required VA attributes. As a result, an alignment between VA practices and business strategies in a value chain can be achieved. In addition, a coalition between SC stakeholders can be formed for data and analytics development and sharing.

In this study, a conceptual framework is proposed for the development of a SC VA covering three main aspects of the system at a macro level: 1) VA-assisted SC decision-making process to align VA with business strategies, 2) data governance strategies to identify and share required data, and 3) VA system development process to streamline SC VA developments. The proposed framework specifies a SC VA system's development process and the inputs, outputs, activities, and involved human agents for each step at a micro-level. The framework facilitates the process of identifying SC decision areas that the VA can support and their alignment with decision goals and business strategies. Moreover, it helps recognize the required data sources and sheds light on data sharing requirements. Finally, it streamlines the SC tailored VA system development process. Indeed, the study results assist SC stakeholders in identifying pitfalls in strategic planning for their VA activities and providing plans to mitigate them. The main contribution of this study is as follows:

- Proposing a conceptual framework for developing SC VA systems.
- Presenting a multi-view representation of the SC VA development.
- Presenting a meta-model for creating SC VA models.
- Providing an overview of existing approaches for VA integration based on the related works.
- Identifying aspects of VA development in SC practices and providing future research directions.

The rest of this paper is structured as follows: In section 2, we present a background of the study covering related works and concepts. Section 3 presents the method for conceptualizing VA development in SC practices. Section 4 provides the proposed framework and explains its different parts and processes. Section 6 highlights the study's findings by discussing its essential aspects. Finally, section 6 wraps up the paper with a conclusion and prospective future works.

2. Background & related works

2.1 Business-driven analytics

Business-driven analytics studies investigate the process of aligning analytical activities in organizations with their business goals and strategies [17]. Previous studies looked at it as a requirement engineering problem from software engineering practice to understand the business goals for which data analytic activities are to be formalized. In this regard, Lavelle et al. [7] proposed a requirement model based on a technique so-called goal-oriented modeling. The model is based on the “i*” modeling framework [18] and traverses the decision-making hierarchy from business processes and strategies to analytical types, decision goals, and information goals. The authors assumed that knowing the business process can be a starting point to determine the scope and objective of the analysis. At the same time, an effective analytical activity requires a more precise analytical goal, such as exploring multi-dimensionality or identifying patterns.

In another effort toward analytical requirement elicitation, Nalchigar and Yu [9] presented a conceptual modeling framework for developing data analytic processes based on business objectives. As part of their framework, they have proposed design catalogs for analytics design. In order to align business issues with the analytical activities, a number of business questions have been categorized based on the possible analytical technique to address them accordingly. In general, design catalogs facilitate the analytical process, especially if it is defined in the context of a specific business domain. Likewise, Golfarelli and Rizzi [19] proposed a design catalog for different visualization types based on a visualization system's six aspects: goal, interaction, user, data dimensionality, cardinality, and type. The goal aspect provides the generic analytical goals, such as composition, order, cluster, etc. A domain-specific goal definition, in our case, SC goals, streamlines the identification of decision goals and eventually results in a better alignment of analytical activity with business processes.

In summary, information system research groups explored business-driven analytics and visualization as a requirement engineering problem. However, the focus on SC requirement analysis and their connection with VA needs more research.

2.2 Supply Chain data governance

SC activities are data-rich, and the information flow within the partners is essential to circulate the desired data for various decision-making activities. However, this raises data control, information security, and data quality challenges. Therefore, there is a need to define data integration and usage policies, data exchange standards, interaction, and collaboration procedures, as well as service level and data sharing agreements [6]. Data governance deals with the control and management of data [20]. It orchestrates data principles, quality, access, lifecycle, and metadata [21]. Apart from the governance of data between partners, the management of data integrity and quality should be handled by each stakeholder to align the business needs with the data and information needs [6]. In this regard, Teruel et al. [22] proposed a modeling language for collaborative BI to foster business-process-oriented decision-making activity, preventing information loss and poor analytical results. Despite several previous works related to data governance [13], [14], [23], SC consortium-specific data governance requires more research.

2.3 Visualization recommendation

During the last five decades, there have been various efforts toward automating visualization type selection and recommending the best visualization type to the user [10], [19], [24]–[29]. In general, the approaches taken by these studies can be categorized into three main types: 1) Task-oriented, 2) Data-oriented, and 3) User-oriented. Task-oriented approaches either focus on the type of analytical tasks, such as descriptive, prescriptive, diagnostic, and predictive analytics, or focus on the specific goal of the user, such as comparison, clustering, and trend analysis. Data-oriented approaches, instead, either rely on the data characteristics, such as dimensionality, cardinality, and data types, or focus on the statistical properties of the data, such as normality of distribution, uniformity of distribution, outliers, and correlation. Finally, user-oriented approaches are mainly based on the user's interaction with the system.

Basically, visualization recommendations are in two ways; 1) providing a ranked list of visuals to users in a faceted view, facilitating the selection of the most desired visuals, and 2) analyzing the interaction between the user and the system, such as zooming and filtering, identifying a meaningful pattern in users' interaction with the system and recommend the best visualization based on previous real-world, observed activities. More recently, Golfarelli and Rizzi [19] proposed a mixed approach by taking into account a combination of these coordinates, such as goal, dimensionality, cardinality, and interaction. However, to the best of our knowledge, previous studies did not consider the SC domain-specific decision areas to recommend corresponding visualizations.

2.4 Supply Chain Visual Analytics

Previous attempts towards conceptualizing VA mainly covered the VA system itself [30] rather than focusing on a specific application area, such as SC analytics. Several studies emphasized the importance of visualization for SC analytics; nevertheless, to the best of our knowledge, there have not been any studies providing a comprehensive SC VA framework. However, conceptual frameworks' use to communicate information systems models has shown to be promising [31]. In this context, Nalchigar and Yu [9] used a conceptual modeling framework to develop an advanced business analytics platform. In our study, we extend this work firstly by replacing the analytic part with a VA module and secondly by focusing on SC specific business activities in the business part. Furthermore, we explore SC stakeholders' required data sharing and governance.

In Wongsuphasawat et al. [32], the authors explored the effects of analysis goals and context on Exploratory Data Analysis (EDA). The authors identified challenges that analysts face during EDA. Two main exploration goals have been mentioned: 1) Profiling: the act of understanding the data and assessing its quality, and 2) Discovery: the attempt to capture insights from the data. The authors discussed that although the EDA literature's primary focus has been discovery, analysts are more involved with profiling activity. Authors in this study added a new phase to what Kandel et al. [33] provided regarding the analysis phases, called the exploration phase. Exploration involves identifying the possibilities within the data by directly playing with the data examining values, statistical analysis, and visualization. This is also a recognized activity in another study by Alspaugh et al. [34]. The authors distinguished between exploratory analysis and directed analysis, emphasizing that exploratory analysis, as compared to directed analysis, does not pursue a clear goal to answer a specific question. Instead, it tries to obtain hidden insights underlying the data. Three main challenges identified during the exploration phase were the time-consuming, unknown goal, and biased outcome. The main point is that almost all of their interview participants said they are using some kind of visualization in their exploration stage, and not only for reporting. Therefore, a proper requirement analysis based on business processes and goals to identify the corresponding decision goals is an essential step in VA activity. The analytical reasoning from SC VA requires a scientific foundation based on theories, models, and evaluations [35].

3. Methodology

This paper proposes a conceptual framework for developing and deploying a VA system applicable to SC stakeholders. The framework provides an abstract platform-independent model for the whole process of VA development. The research methodology is represented in Figure 1.

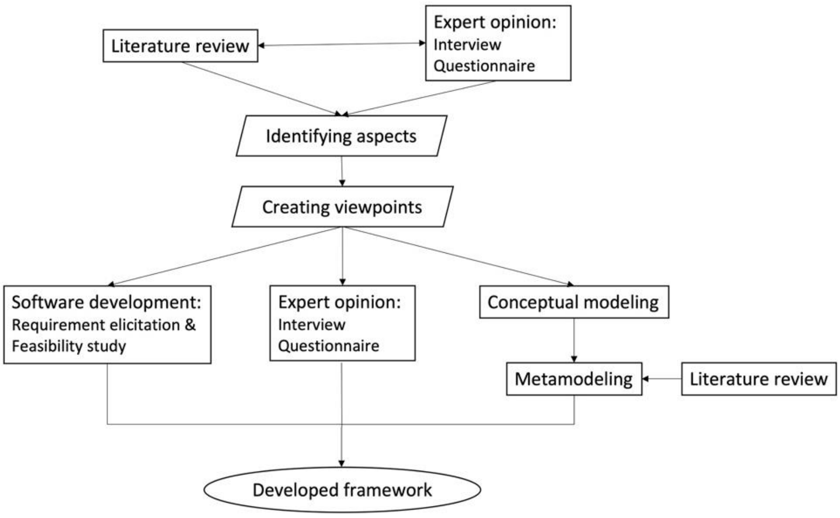

Fig. 1. Research Methodology

3.1 Qualitative approach

The methodology to develop the framework begins with a combination of literature review and expert opinions, from which three aspects as a basis for the development of the framework were identified: 1) goal-oriented data analytics, 2) data governance, and 3) domain-specific VA development. Based on these aspects and adapted from Nalchigar and Yu [3], we created three viewpoints to include the process steps related to different stakeholders and to elicit requirements and specifications of different stages of the process.

Therefore, our representation of the SC VA framework comprises three views as the main pillars of the framework, namely, 1) Business view, 2) Asset view, and 3) Technology view. Each of these views covers a set of steps in its context to facilitate the development and maintenance process. The software development process introduced by Sommerville in [36] was used for the business requirement elicitation and feasibility study in the business view. Furthermore, collecting domain expert opinions (SC director, data platform engineers, and visual analytic developers), both by means of interviews and questionnaires, led to the formulation of the asset view. The interview and questionnaire aimed to determine the following:

1. What are the data analysis tasks they perform?
2. What are the current tools they use?
3. What type of data is used?
4. How are the data collected and stored?
5. What are the results of the analysis being used?
6. What are the gaps in current data analysis and visualization practices?
7. What are the requirements?

The participants for the interview and the questionnaire need to be among the following: 1) Solution developers as enablers of data analysis and visualization, 2) Data analysts as providers of data analysis and visualization, and 3) Decision-makers as users of data analysis and visualization. However, it is not feasible to find many such actors as the participants, given there are not many visual analytics solution developers within our reach. Therefore, we only used questionaries and interviews as a tool to communicate with the most suitable and well-informed contacts we had. This can be identified as a mixed purposive and convenience sampling technique [37]. In this regard. we provided the questionnaire to an IT company providing such solutions to SC actors and conducted semi-structured interviews with the SC director of a Norwegian food producer using these solutions as both data analysts and decision-makers. The questions for the questionnaire and the interview was developed based on the guidelines provided by King et al. [38]. Adapted from the guideline we carry out four main tasks as follows:

1. Framing the research question.
2. Choosing the type of data collection (interview/questionnaire).
3. Defining the sample and recruiting participants.
4. Developing an interview guide.

The guide for the interview and the questionnaire is formulated based on a set of questions and answers presented in Table 1. The complete guide along with the questions are presented in Appendix A. Consequently, one of the authors recorded and transcribed the interview. We then used descriptive coding for both the interview transcripts and the open-ended questionnaire. From the coded data we identified the most relevant information to our problem domain and made conclusions.

Table 1. Questions and answers to create the interview guide.

Questions	Answers
Upon what do we base our guide?	▪ Personal experiences ▪ Other’s experiences
How comprehensive should we be in covering topics relevant to the research area?	▪ Enough comprehensive to cover key aspects of the aims of the study ▪ Narratives for particular cases
What types of questions should we ask?	▪ Experience questions ▪ Opinion questions ▪ Knowledge questions ▪ Information questions
How to format questions?	▪ Open-ended Question format

3.2 Conceptual modeling and metamodeling

Conceptual modeling [31] suggests using models within each viewpoint as an abstraction technique to consider a specific set of concepts within the system [39]. Within conceptual modeling, meta-models [40] facilitate the generalization of the framework to fit different SC stakeholders’ scenarios. Meta-models provide the capability of dynamic stakeholder extensions and the interchange of model concepts to the framework [41]. Using meta-models, we can tailor the visualization models for different stakeholders both externally across the SC partners and internally across each organization’s departments. For example, the framework can be used to develop visualization models for the marketing department of a manufacturing company as well as the operation department of a warehouse company.

During the model-building process, we need a language as a medium for representing concepts. We used Domain-Specific Modeling Language (DSML) to build a platform-independent approach for VA and Unified Modeling Language (UML) notations to create our meta-model for the technology view.

Simultaneously, we used the findings of our previous systematic literature review study Khakpour et al. [1] as a catalog to create the meta-model. We also created a usage scenario by collaborating with a manufacturing company from a food SC. The usage scenario describes a real-world example of the envisioned usage of the framework. Hence, we conducted interviews with participants from the company to identify their goals and integrate their existing VA activities into the proposed framework.

3.3 Hybrid agile-waterfall approach

Inspired by the manifesto for agile software development [42], the framework design follows a hybrid agile-waterfall approach to benefit most from the two methodologies [43]. A waterfall strategy is used to design the overall procedure of the framework, reflecting the ultimate goal of the framework regarding requirement abstraction. Essentially, waterfall models are suitable when requirements are stable in nature [44]. However, once the requirements concerning business goals and data are identified, agility is needed in the visualization development process concerning decision goals. Therefore, we proposed the visualization design based on an agile strategy. An initial visualization model will be developed and go through a feedback loop with the user(s) before it proceeds with implementation. In this way, the analysts are in continuous communication with the consumers of the analysis, and the final visualization dashboard will be delivered with a better alignment with the decision goals.

4. Supply Chain Visual Analytics conceptual framework

The overall representation of the framework is shown in Figure 2. In the following section, we also explain each layer and its steps.

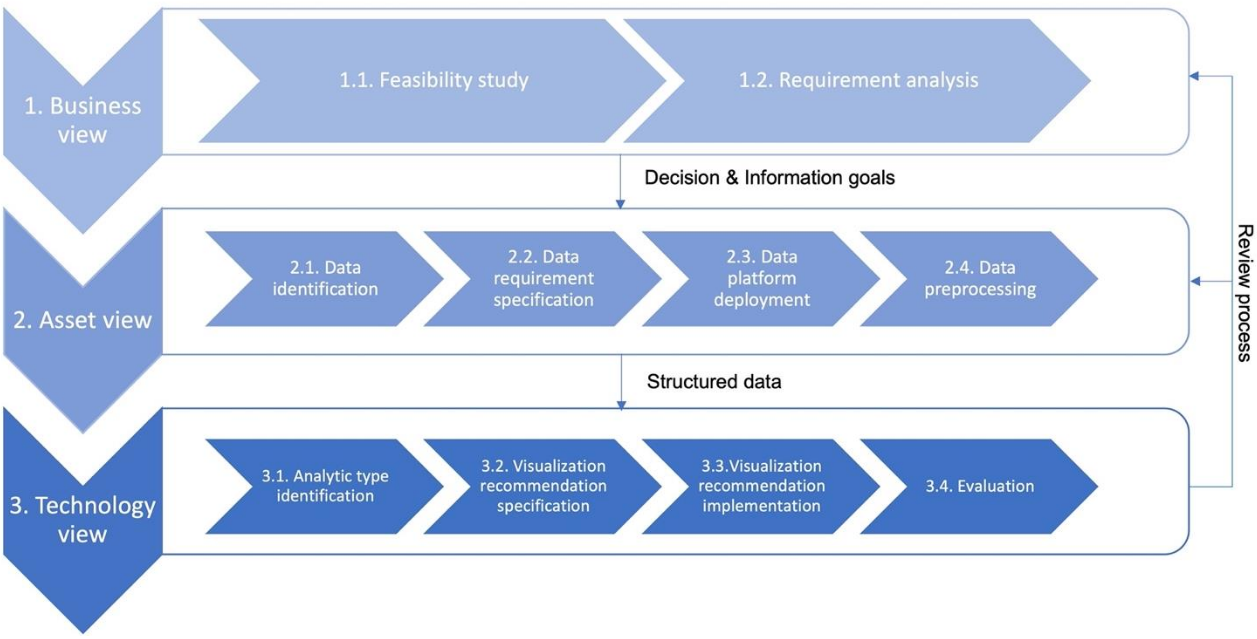

Fig. 2. The proposed framework

4.1 Business view

We start with the business view, where the business requirements should be identified and analyzed from the stakeholders' point of view. "Requirements are usually understood as stating what a system is supposed to do, as opposed to how it should do it. However, understanding the organizational context and rationales (the "Whys") that lead up to systems requirements can be just as important for the ongoing success of the system" [45].

Firstly, it is required to investigate how feasible the development and deployment of a VA system into a certain business area is for different objectives. For example, a visualization system may be feasible in the marketing section of a company, rather than in the manufacturing section, given that the company is more marketing oriented. The feasibility study also justifies the need for investment both in terms of infrastructure and human resources. To identify the requirements, we need to identify 1) Users of the system and 2) Business processes.

The feasibility of a proposed system should be considered from both business and technical stakeholders' points of view. However, depending on the size of a business, corresponding roles may overlap. For example, in a medium-scale company, a SC director may also carry out data science tasks. Therefore, various stakeholders' involvement is not described explicitly. Instead, we tried to focus on the required objectives and outcomes of the feasibility study. The feasibility study begins by interviewing the company's executive directors to understand the business objectives and strategies and to identify if the deployment of a VA system will align with the business requirements. At this point, the input to the feasibility study is business domain knowledge, business requirements, and current resources and operations of the organization, and the output will be an assessment of the extent to which a VA system should be implemented. The feasibility study is, in fact, part of the requirement analysis step where interviews with the system stakeholders, such as business directors, analysts, and decision-makers, help to understand the requirement of a prospective VA system.

Moreover, to formulate a useful VA task, it is required to identify decision goals that the VA intends to support [29]. Decision goals can be identified from business processes and issues. At the same time, information goals need to be recognized, being the desired information that stakeholders seek to analyze [8], both of which can be identified from understanding the business processes and goals. Finally, requirement analysis is also concerned with understanding the skill level of users to design the VA system accordingly. Later on, required skills can be taught to users through training and workshops. In this regard, corresponding tasks include (i) defining the system requirements based on business strategies, (ii) identifying business processes that VA may support, (iii) understanding the business issues and defining decision and information goals, (iv) identifying target user skillsets, and (v) planning user development strategies.

4.2 Asset view

Asset view deals with the company's data assets, including identifying the available data sources, data requirement specification, required data platform description, and data pre-processing. This stage gathers and prepares the required data for analytical activities. Data identification deals with information sharing throughout the SC partners. Corresponding tasks are a collaboration with multiple partners to identify the available data and streamline the process of sharing the data. SC partners are increasingly required to share both third-party data and their collected data to optimize and improve SC operations [46]. This includes sharing collected data that can contribute to the development of analytical activities from various sources, such as freely provided data, observed data, derived data, and inferred data [47]. In this regard, various partners should be informed of the mutual benefits of cooperative analytical activities. On the other hand, the data governance aspects such as data quality assurance, security, and privacy should be handled with the help of data engineers and security experts under the asset view of the framework. Abraham et al. [6] describe these activities as part of the governance mechanisms to retain control over organizational data.

Then, the decision and information goals identified in the earlier stage should be mapped to the available data sources. This process would be the result of the collaboration of data scientists having acquaintance with the data needs and SC directors having the authority to negotiate with their peers among SC partners. It may be required to define new data collection procedures to gather required data from new sources. Here, data scientists describe the metadata for all the available data and provide a plan for future metadata definitions. Additionally, data scientists collaborate with data engineers to perform the required activities related to the pre-processing of the data, including data integration, cleaning, transformation, and data characterization. Kandel et al. [33] describe the data preparation process as four high-level tasks: data acquisition, wrangling, modeling, and profiling. The authors identified data integration from various data sources and visualizing data at scale as the main challenges of the data analytics process. Eventually, the identified, pre-processed structured data will be available and ready to be analyzed in the VA phase of the framework.

4.3 Technology view

The goal of the technology view is to identify the required analytical goal and create a formal visualization specification language to facilitate the process of creating a goal-oriented VA output. The first task is identifying the analytic type based on the decision goals identified in the requirement analysis phase. Analytics type can either be descriptive, diagnostics, prescriptive, or predictive. Corresponding actors in this process are data analysts and data scientists. The second task is to automate the process of converting an analytical goal into a visualization specification, which is mainly done by VA solution providers who build VA tools. For this purpose, a domain-specific modeling technique can be used to satisfy the goal-oriented visualization development [48]. In this regard, integrating the SC decision domain categorization from Khakpour et al. [1] provides a means to create a decision goal-based model. Based on this study, corresponding domain decision goals can be the identification of sales strategies, sales management, collaborative forecasting, network integration and visibility, production and distribution planning, demand management, SC network design, and transportation and operation management. This kind of taxonomy of decision areas helps further to identify corresponding visualization tactics and required data types. In this view, we created a meta-model based on the catalog presented by Khakpour et al. [1]. The meta-model is created using the graphical modeling of Eclipse Modeling Framework (EFC) as a tool. Figure 3 depicts the simplified version of the meta-model. The description of the model is as follows:

1. A dashboard is a superclass that can contain multiple visualizations.
2. Each visualization is a separate entity that pursues one-to-many VA goals and supports zero-to-many decision areas. It also explores the corresponding data source.
3. Each decision area has on- to-many corresponding data sources.
4. Each VA goal is achieved through one-to-many visualization tactics that use one-to-many visualization techniques.
5. Each visualization technique is associated with one-to-many analytics types.

Further on, the visualization expert will generate a visualization specification that provides a detailed description of the visualization presentation and the dashboard. This is where a DSML will be generated to implement the visualization specification defined. Then, the DSML will translate into a visualization dashboard using a code generator, such as Vega-Lite visualization grammar. Vega-Lite is a high-level visualization grammar that uses JSON format to translate visualization specifications into interactive visualization designs [49]. Vega-Lite is an example of a tool that enables the implementation of visualization designs from the visualization specifications. Finally, the developed visualization dashboard goes through another review process with the involvement of stakeholders from previous views to ensure alignment with decision goals and data requirements.

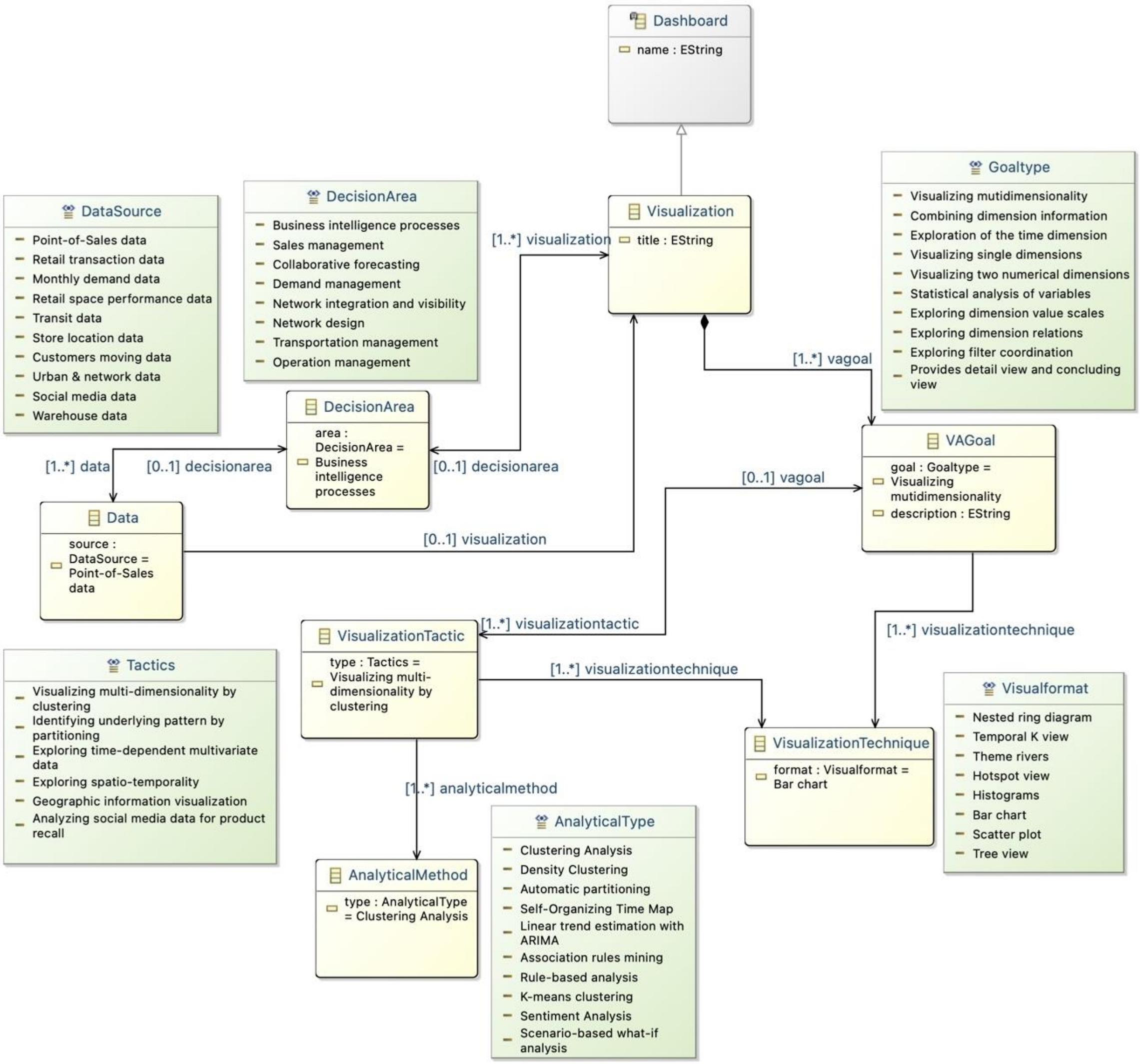

Fig. 3. SC VA meta-model

5. Usage scenario

The usage scenario here describes a real-world example of how to use the proposed framework. We consider the case of a manufacturing company (XYZ, anonymized name) that produces different types of confectionaries, nuts, and dried fruits. They collect and store data from various sources, both internally from their operations and externally from their SC partners. XYZ intends to exploit the potential of its data assets and improve its processes and decision-making activities with VA. Currently, the company does not have any VA system in place, and managers use some of the commercial out-of-the-box visualization tools. This makes the VA activities inefficient and loosely coupled with companies' business processes and goals. Figure 4 shows the instantiation of the framework for this example.

Fig. 4. Instantiation of the framework for the example

5.1 *Business view*

The first step is to check the feasibility of implementing a VA system in the company's current operations (1.1. in Fig. 4). In this regard, we interviewed the SC director of the company as the person who is in charge of creating strategic plans for future developments of the business processes. During the interview, he stated that although the existing out-of-the-box VA systems are not feasible for their size of company and operations, they are optimistic about the future development of such technologies for their operations, as he described:

"*We are a small company, so many existing solutions are not so relevant for us. As IT technology becomes cheaper relative to costs and gains, the benefit ratio changes in time so we can prepare for future solutions like point of sales data. We should run at a point where these are available. 90% of our demand is covered by point-of-sales data. So, we can have a better forecast. Finally, log all the data and visualize to see what is going on.*"

At the same time, XYZ presents challenges in collaborating with their warehouse partner (1.2. in Fig. 4). They acknowledged that the amount of work at the warehouse is highly correlated with the sales forecast. For instance, they can predict the workload at the warehouse if they know what type of products they sell more (either single products or mixed products). In this scenario, they inform the warehouse partner about the number of people the warehouse needs in the following months, which is crucial for the warehouse's profit making. Based on the feasibility study, defined as part of the framework, the company needs to answer at least two main questions regarding the feasibility of deploying a custom-made VA system: 1) Will the system contribute to the overall objective of the company? And 2) What are the current approaches, and how can the system be integrated into existing systems?

Within the business view part of the framework, we identified that a VA system could contribute to the overall objective of the company by 1) Collaborating with the warehouse partner by forecasting the main drivers for the amount of work at the warehouse and 2) The root-cause analysis of the events within historical data. Both aspects contribute to improving the decision-support activities of the company. We also identified that currently, the SC director collects the data from the warehouse partner manually, although he mentioned it is also possible to fetch the data through an Application Programming Interface (API) from the Warehouse Management System (WMS) to the company's BI system. In this regard, the framework can assist with creating the required data ingestion pipeline as part of its asset view. Therefore, answering both questions lead to accepting the feasibility of deploying a VA system for this purpose. At the same time, the company's business requirements regarding the decision goals and information goals are recognized.

5.2 Asset view

XYZ gets invoices from the warehouse partner every month reflecting its services as part of a management report (2.1. in Fig 4). The final amount of the invoice is calculated based on the number of pallets stored and the number of cartoons that enter and leave the warehouse, so-called key payment indicators. The main key payment indicators affecting the invoices are based on two primary warehousing factors: 1) How much of the warehouse is being used, called storage, measured by the average number of pallets going into the warehouse in a month. 2) Handling cost: measured as transactions, basically the number of pallets going into the warehouse calculated by the WMS and the number of pallets going out of the warehouse plus the number of cartoons being picked. That is the second biggest key payment indicator contributing to the cost of warehousing. The corresponding data goes back in time to 2014. This is where visualization of the data can help demonstrate and compare the workload at the warehouse in different months and identify significant historical changes that are not due to typical annual seasonality.

The information goals here are to identify whether there are significant changes in the monthly warehouse transactions or not, and if so, what the reasons behind these changes are. The company also has some raw materials, finished goods, and trading goods in the warehouse. Consequently, the changes in transactions can either be due to changes in raw materials, changes in production plans that are making much larger production batches or buying more trading goods. The decision goals would be to optimize how many people the warehouse needs daily, how much power time, and how many extra people and temporary workers they need.

The next step is to map the decision and information goals with the required data. In this regard, the main activity is facilitating the data-sharing process with the warehousing partner. From the interviews, we found that the warehouse managers are aware of the mutual benefits of the resulting VA since they did previous pilot test cases and are willing to share their data instantly. This data is present in their WMS, and the company's data engineers can create an ingestion pipeline to collect the data using an API to the existing BI system, where the visualization can be created. This is the data identification step within the asset view of the framework. This follows the data requirement specification step, where the main activity is to ensure the data governance of the shared data (2.2. in Fig. 4). A data-sharing agreement with the warehouse partner should be made to determine the data-sharing policies within the partnership. This is where data integrity and quality management will be handled to align the business needs with the data and information needs.

Currently, the required data is not in the company’s BI system. Although it is possible to fetch it from their ERP system periodically, it will be more beneficial to fetch the data from the WMS of their warehouse partner in real-time. This activity is related to the data platform development step of the asset view (2.3. in Fig. 4). The data collection pipeline should facilitate the ingestion of the warehouse data in real-time into the BI storage system for further processing. The extracted data is unstructured and needs to be pre-processed to foster the desired analysis (2.4. in Fig. 4). Pre-processing requires data scientists to perform data acquisition, wrangling, modeling, and profiling. During the data acquisition, data should be located within the BI system. During the data wrangling process, other available data may be ingested and integrated into the analysis, such as inventory data from the ERP system. Then, within the data profiling activity, the quality of the data should be verified by identifying possible errors in the data or any missing data points. Finally, data modeling involves feature selection and feature engineering processes to create final structured data ready for VA.

5.3 Technology view

This layer of the framework deals with the analytical part of the system deployment. Firstly, based on the decision goals, the desired analytical type should be defined (3.1. in Fig. 4). Given the current decision goals, the corresponding analytical type would be predictive analytics which attempts to visualize the amount of work in the warehouse in the following months. This is also descriptive analytics that will show the reason behind historical changes in warehouse transactions. In this regard, a domain-specific visualization model should be created based on the data specification and analytical goals identified (3.2 in Fig. 4). Based on the meta-model created in section 3, the following visualization model was created for this example (Fig. 5).

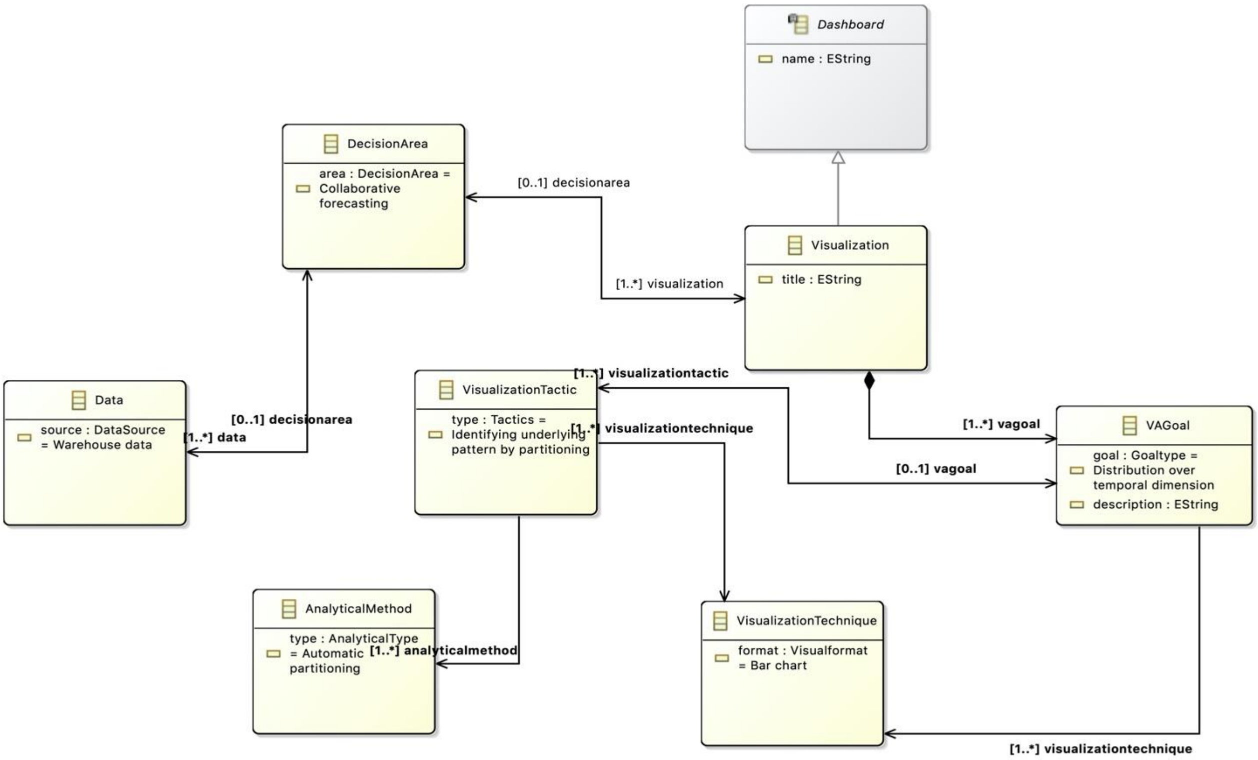

Fig. 5. Visualization model for the example

Following the creation of the visualization model, the DSML will be used to implement the visualization model into a dashboard (3.3. in Fig. 4). Vázquez-Ingelmo et al. [40] presented a DSML to implement visualization in different application scenarios. This can be adopted for the SC application area. This process will create a visualization dashboard which will be presented to the user for a final round of review. The users will interact with the dashboard and have the opportunity to get design alternatives. It is also possible to modify the requirements and repeat the process (Fig. 3).

6. Conclusion and future work

In conclusion, we first attempt to explicitly clarify three significant issues that we considered in this study:

1) How is VA preferable to statistics for data analytics?

2) What are the challenges of integrating VA into SC business activities?

3) What are the benefits of using domain-specific modeling techniques, specifically DSML, UML, and code generation, to address those challenges?

Regarding the first question, we argued that the vast amount of data generated and collected within SC activities need some form of exploratory analysis to identify hidden insights underlying the data. Statistical analysis often has a clear goal to answer a specific question, is time-consuming, and is biased with presumptions. On the contrary, VA provides unbiased data exploratory analysis by visualizing different contexts of the data and letting the analyst discover the unknowns. To answer the second question, we refer to the three main challenges: 1) There is a misalignment between VA activities with business processes and decision-making activities, 2) There is a need to locate and consolidate data from different sources, and 3) Selecting and using the best VA approach is a difficult task and needs particular expertise.

To address these challenges, we proposed a conceptual framework to provide an abstract platform-independent approach for the development and deployment of VA in SC application areas, which relates to the third question. We identified that a goal-oriented VA, based on a domain-specific modeling framework, can streamline the process of VA development. However, there is a gap between the visualization experts who build VA tools and the domain experts who use the tools for their analytic activities.

Furthermore, VA tools do not support the entire pipeline of decision-making, which is identifying the business goals and decisions and deciding on the visualization task and suitable visualization design. A solution is to program VA. However, not all domain experts and visualization users can write programs. On the other hand, not all visualization experts that can develop customized visualization using programming understand the domain aspects. Therefore, domain-specific modelling techniques such as DSML, UML, and code generation can be used to define the visualization tasks using modelling and domain concepts and fill the gaps between VA and domain experts. In this regard, based on conceptual modeling and metamodeling, we created a hybrid agile-waterfall representation for the framework covering three main levels of the process.

Firstly, to align the VA with the business goals, having a goal-oriented VA, we need to elicit the analytical requirement from the respective stakeholders. This is the main aim of the business view part of the platform. Every step is related to certain actors that help perform the tasks and achieve the goals. For example, one of the main participants in SC practices is the SC director, who is usually in charge of developing productivity, quality, and efficiency of operations. They analyze existing performance data and produce forecasts to develop better strategic plans. They typically take reports from analysts and report to top-level managers. Therefore, they are the main actors in the requirement analysis step of the framework. This process starts with a feasibility study by considering the business strategies and goals and producing the decision and information goals as output.

Later on, the asset view deals with data collection and integration. The data then needs to be gathered and collected in a data platform to streamline the process of data pre-processing. The primary data pre-processing challenges identified are data integration from various sources to visualize data at scale. This stage's main actors are data engineers dealing with data integration, cleaning, transformation, and data characterization. Moreover, the data governance aspects of the data integration should be handled with the help of security experts, where data quality assurance, security, and privacy are the main aspects to consider.

Finally, we define the VA specification and analytic type. Based on this, an implementation of the VA will be carried out. We presented the VA specification as a modeling activity, where a domain-specific modeling technique will be used to align the decision goals and VA outcomes. Eventually, a visualization meta-model was created. To demonstrate the application of the framework, we presented a usage scenario based on a real scenario of a confectionary manufacturing company. Such a scenario shows that the proposed framework achieves its intended goal.

In future work, we plan to implement the framework in a set of organizations to evaluate its applicability and identify possible improvements more broadly. In this regard, we may need to extend the meta-model as the centerpiece of the process to be more comprehensive in the case of SC activities but also calibrate the model to adapt it to the actual needs of organizations. The future work also includes the development of a DSML for our particular application domain, SC VA, which also requires the integration of a code generator and testing it in a real application scenario.

Acknowledgments

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Appendix A. Road Towards Interview and questionnaire guide

Steps	Questions	Answers
1	What is the aim of the project?	▪ Exploring and integrating VA in supply chain activities.
2	What are the project research questions?	▪ What are the available and required data for VA in supply chain? ▪ How the VA techniques can be used in supply chain activities?
3	What is the aim of the sub-project?	▪ Understanding the current practices and requirements.
4	What are the sub-project research questions?	▪ How are the current VA practices are conducted? ▪ What are the requirements for future VA practices?
5	What is the aim of the study?	▪ What are the current VA practices? ▪ What are the challenges?
6	What are the research questions for the study?	▪ What are the data analysis tasks they perform? ▪ What are the current tools they use? ▪ What type of data is used? ▪ How are the data collected and stored? ▪ What are the results of the analysis being used? ▪ What are the gaps in current VA practices? ▪ What are the requirements?
7	What are the priori and/or posteriori to look for?	▪ What is the current VA framework and what would be the desired VA framework?
8	What are the constructs of either the priori or the posteriori?	▪ Available types of Data. ▪ Current data collection techniques. ▪ Current data Storage means. ▪ Any VA tasks. ▪ Any VA tools.

9	What is the guideline?	▪ Available Data? ▪ Desired Data? ▪ Data Collection? ▪ Data Storage? ▪ VA Tasks? ▪ VA Tools? ▪ VA Gaps? ▪ VA Requirements?
10	What are the Questions?	▪ Regarding the data collection strategies (if possible, walk us through an example). ▪ What are the data collection tools you are using? ▪ What are the data warehousing tools you are using? ▪ Do you use any ETL/ELT architecture? If yes, which technologies do you use? ▪ How do you connect the data from existing systems such as SAP ERP to a BI system? ▪ Regarding the data analytics strategies (if possible, walk us through an example). ▪ How do you identify data analytics tasks? ▪ Which analytical techniques do you use? And how do you choose them? ▪ How to locate the required data? What are the main data sources? ▪ Regarding visualization strategies (if possible, walk us through an example). ▪ What are the visualization tasks you perform? ▪ Which visualization tools do you use? Do you see any shortcomings? ▪ How do you integrate visualization practices into your activities? ▪ What are the challenges in visualization tasks using current tools? ▪ Supply chain analytics. ▪ What type of data platform technologies do you use? For example, regarding data warehouse, data hub, and real-time components. ▪ What are the key challenges you face in using data analytics platforms and any prospective plans to handle them? ▪ Do you have any specific analytical teams in the company? How are they communicating with other sections?

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He received a bachelor's degree in information systems and Engineering from MSRIT. He then continued his studies by receiving his first master's degree in Software Engineering from Azad University, and later by receiving his second master's degree in Applied Computer Science from Østfold University College. He is now working as a Doctoral Research Fellow at Østfold University College and as a PhD Candidate at the University of Oslo. His PhD title is "Information sharing for customized dynamic visual analytics". Alireza's main research interests are in Machine Learning, Visual Analytics, and Information Systems. As part of his PhD, he is working on a project called DigiMat which has its aim in making the Norwegian food supply chain, smart, transparent, and sustainable.

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Abstract:
As one of the leading causes of project failures, requirements changes are inevitable in any software project. Hence, we propose an intelligent approach to facilitate the risk analysis of a change request by providing information about past cases found in similar change requests, the solutions adopted, and a support tool. The proposed approach uses case-based reasoning to retrieve previous cases similar to the current case. This approach also uses association rules to analyze patterns in the dataset and calculate the probability of risks associated with change requests. We prepared a case study to validate the proposal by analyzing the most frequent challenges in change management and considering how it can solve or minimize such problems. Results show that the proposed approach successfully assists decision-making, predicts potential risks, and suggests coherent solutions to the user. We have developed a support tool to evaluate this approach in practice with experts and obtained four different outcomes. Only a small set of cases failed to provide relevant results to the user. The use of case-based reasoning and association rules has proven to be advantageous in change management despite validity threats associated with the small number of test cases and experts involved.

Keywords:
change management process; change request; risk management; case-based reasoning; association rules.

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1. Introduction

Requirements changes are inevitable to satisfy the project stakeholders' needs and goals. As software evolves, this scenario becomes a problem. Unplanned changes can result in inconsistencies and errors, requiring the work to be redone and the system to be redesigned. This situation causes an increase in costs and the need for deadline rescheduling and team task reallocation. Apart from additional development phases, the team needs to test to ensure the software will work with the changes made [1]. Requirements change is one of the primary causes of failure in software projects [2]. Therefore, defining a systematic process ensuring that changes are controlled from request to delivery and that stakeholders are informed about the progress and impacts caused by them is necessary. Andrew et al. [3] performed a Systematic Literature Review to identify the most significant studied challenges of the Requirements Change Management (RCM) process. According to the authors, the most cited challenge is impact analysis, and cost and time estimates are also critical aspects. Therefore, searching for techniques that facilitate these tasks for professionals in the area is necessary.

Learning from past experiences is common in software engineering [4][5] and is particularly useful in facilitating cost and risk analysis activities [6]. From another perspective, this learning dynamic takes time and usually provides subjective results, so artificial intelligence (AI) techniques can improve it [4][5]. Intelligent systems have assisted human beings in performing tasks by replicating a person's reasoning to solve problems [7]. AI's relationship with software engineering subareas, such as change management, tends to generate beneficial results [8]. Software engineering is a knowledge-based area, but professionals have to deal with uncertainty most of the time. With the aid of techniques and algorithms provided by AI, such uncertainty can be reduced [4]. In RCM processes, AI techniques have improved tools that support managers and software engineers [8].

An intelligent tool capable of predicting and evaluating possible risks of incorporating a new change in a project can help professionals make a better choice when deciding, thereby minimizing the negative impacts or the probability of problems associated with risks caused by a change request.

Given these considerations, our goal is to propose an intelligent approach that facilitates the risk analysis of a change request by providing information about past problems encountered in similar change requests, the solutions adopted, and a tool to support it. This approach uses Case-Based Reasoning (CBR) and association rules techniques.

Change requests are represented as cases and stored on a case base. When evaluating a new change request, the manager can retrieve similar cases to reuse past information as identified risks and associated estimates. We chose to use the CBR technique as it is suitable for decision support systems for helping to identify possible problems and how they can be solved through past case retrieval. In addition, this technique is suitable for the goals of this research owing to its particularities, such as low-cost incremental learning and recovery of solutions in a language understandable by the user based on the human logic of solving problems [9][10].

We use a hybrid approach between CBR and Association Rule Mining (ARM), a popular technique for knowledge discovery in data mining, to improve the accuracy of the results when evaluating the risks of a change. The integration of both can provide positive results, particularly in complex applications that do not have a large case base, making it difficult for the case retrieval algorithm to obtain relevant results. Therefore, ARM can be a technique to discover interesting relations between attributes in the case base and thus enhance the problem-solving capabilities of CBR through the analysis of these associations [11][12][13].

In the validation, according to the literature, we focused on evaluating whether the proposed approach helps the team solve the most common problems in change management. We invite project developers to assess change requests using our approach to achieve this goal. They entered project change requests and provided feedback on the responses' usefulness.

The paper is organized as follows. Section 2 describes background information about the change management process and AI techniques, and Section 3 presents the related work. Section 4 details a proposed approach and its activities. Section 5 describes the research validation methods and discusses the results obtained. Finally, Section 6 concludes the study by describing the final considerations and discussing future works.

2. Background

This section briefly describes the concepts necessary to understand the rest of the article.

2.1 Requirement change management

Changes are inevitable in any project. Users are unlikely to be able to define all software requirements at the beginning of development. Hence, the team often requests changes [14]. Change requests address not only new or changed requirements but also bug fixes and defects. Change requests are reviewed to determine the impact the change will have on related artifacts (source code, models, diagrams) as well as budget and schedule [1][15].

According to the CHAOS Report, the frequent change in requirements is one of the main challenges of projects, only behind incomplete requirements and the need for more cooperation between the team and the client [2]. In addition to being a significant difficulty for the team, how changes are managed can impact the success or failure of a project, leading to business losses owing to lost time and the need for rework. Iriate and Bayona [16] conducted a systematic review of the literature, where they collected 263 success factors, and the second most cited factor was change management.

Researchers estimated that the impact of changing requirements on industrial projects is between 40% and 90% of the total project cost [14]. Therefore, defining a change management process can minimize the negative impacts of a change over the life cycle of the software project [1][15].

The RCM process begins when a stakeholder completes and submits a change request that describes the required change to the system. After submitting a change request, the team evaluates its validity. This verification is needed because not all change requests require action [1]. For example, a reported bug may already have been fixed, or new features are already planned to be incorporated into the software. In these situations, the change request is closed, and the form is updated with the reason for closing [15].

For valid change requests, the next step is to assess the impact of the change. Generally, this task is the responsibility of the development team. The team must identify all affected components, the risks involved, and the estimated cost and time of making the change to evaluate the impact of the change [1][15].

After this analysis, the Change Control Board (CCB) decides whether, from a business perspective, the change should be made. This group is responsible for reviewing and approving change requests before they are implemented [1][15].

Andrew et al. [3] analyzed 43 articles related to challenges in RCM, with 32 on general problems and 11 specifics to Global Software Development (GSD). Then, they identified the main issues commonly faced by professionals. Finally, for each one, the authors calculated its frequency of occurrence in the selected papers. Given that this study does not focus on GSD, we only consider the 10 general challenges in RCM and their frequency of occurrence.

Andrew et al. [3] concluded that impact analysis is the most cited challenge (67%) and requires a thorough analysis of the new state of the system, consistency with existing business goals, and impact on other operational constraints. Cost and time estimates are critical aspects of project management mentioned in 25% and 12% of the papers, respectively. Another crucial challenge in the RCM process is the management of artifact documentation, which is mentioned in 25% of the documents. Requirement traceability and dependency are cited by 22% and 16% of the works, respectively. Change conflicts with existing requirements are noted in 12% of primary studies. The authors mentioned other challenges, such as change prioritization (6%), user involvement (6%), and system destabilizing (3%) [3].

2.2 Case-Based Reasoning

CBR is a paradigm in the AI area for reasoning and learning from past experiences. A reasoner retrieves and reuses similar past experiences to solve a new problem. This way, they can interpret it and discover ways of solving it. This technique is usually associated with how the human brain works when information stored in our mind is retrieved to create an answer to a problem [17].

In CBR, an experience is described as a case and stored in a base that contains many others. A case necessarily has two pieces of information about experience that are important for reasoning: the description of a problem and the solution adopted for its solution. A solution is not always successful, but it should be stored [18].

2.3 Knowledge Discovery in Databases

Knowledge Discovery in Databases (KDD) is a process of extracting information from databases. This process covers the essential steps for retrieving relevant data in mining, from preprocessing data to analyzing and interpreting the results. The initial preprocessing step consists of preparing the data for mining. There are usually null or inconsistent values that can generate incorrect results and need adjusting by the programmer. Therefore, only the relevant attributes are selected at this stage. After preprocessing, mining methods can be effectively applied to the data depending on the developer's wants. One of the most common techniques is ARM [11].

ARM is the procedure of finding frequent relationships between items in large datasets. These relations are expressions of form $X \rightarrow Y$, where X is a premise and Y is a consequence of this premise. Such associations consider two key measures: confidence and support of a rule. Confidence in data mining is the value that indicates how often a given premise and a consequence are true, that is, the percentage of times a given rule has occurred. This measure is highly associated with support, which indicates the frequency of occurrences of an item in a dataset. Confidence and support define an association rule [19][20]. Once the chosen algorithm has mined the data, it goes through a postprocessing step to clarify the visualization to the user. Finally, the last phase of the KDD process consists of the interpretation and analysis of what was obtained in the previous step to extract knowledge about the data.

Using different AI techniques to complement CBR is becoming more common. New hybrid methodologies seek to reduce disadvantages and increase the positive aspects of applying the techniques separately, thereby bringing greater precision and efficiency to an intelligent system [21].

The AI techniques are adequate to assist the team in change management activities, as they seek to replicate human intelligence [7]. Similarly, activities in the area of software engineering deal mostly with knowledge [1][22]. Among the AI techniques, we consider that the use of CBR is adequate, as it is commonly used in decision support systems [23], providing the user with ways to identify and resolve adversities in a "problem-solution" format similar to reasoning used by the human mind [9]. Even so, its use may not guarantee a complete understanding of the information. Therefore, the association rules are an ideal complement to bring greater precision and knowledge of the results obtained.

Based on several readings in the transaction database, the Apriori algorithm [24] is one of the best-known algorithms for mining by association rules, being able to work with a large number of attributes. The algorithm employs depth-first search and generates sets of candidate items. The entire database is crawled, and frequent itemsets are obtained from candidate itemsets. Infrequent patterns are eliminated. In Abid et al. [25], the authors used the Apriori algorithm to generate association rules that link source code and interface-level metrics with the quality of service.

Corners and Matties [26] argued that project documentation represents a valuable source of knowledge in project-based organizations. However, reusing knowledge encoded in design documents in future projects is not easy. The authors in the literature review pointed out that efficient tools to assist in the reuse of coding knowledge in project documents are lacking; therefore, this process is costly and time-consuming.

3. Related work

Change management processes depend on tools and techniques to support their activities and make their execution more efficient. Currently, numerous researchers proposed different solutions to ease the management of a change request.

Ali, Iqbal, and Hafeez [27] proposed a framework for RCM based on the CBR technique in the GSD context. GSD refers to software development by teams in various parts of the world. By applying the CBR-based framework in the cloud, the authors noted that the communication and coordination of the global teams during change management, which was previously challenging, became more effective. In addition, the services demanded were always available on a single platform without time and space restrictions, unlike when the team used tools on different sites.

Naz et al. [28] proposed a model that integrates RCM with the CBR technique. To validate the work, the researchers presented the framework to specialists and, later, asked them about factors such as customer satisfaction, history maintenance, and analysis of the impact on cost and time. The framework can help improve the factors listed by researchers.

Other authors proposed using techniques other than CBR for RCM. Tomyin and Pohthong [29] proposed a model based on object-oriented software engineering and the Unified Modeling Language (UML). Alsanad, Chikh, and Mirza [30] created a framework based on a multilevel ontology. Satyarthi and Pandey [31] developed a framework for managing change using a traceability matrix.

This work differs from the others as we focused on defining an approach to evaluate requirements change requests based on integrating ARM and CBR and developing a tool to support it in software projects. Given the proposed approach, the purpose is to assist users in analyzing risks that can occur during the implementation of an approved change, improving the change impact evaluation and effort estimations from the reuse of past cases.

Ali et al. [27] and Funk and Xiang [12] used CBR but did not explicitly support the same goals. In Ali et al. [27], the proposed framework aims to ease communication and control in teams with members scattered globally. In Naz et al. [28], the framework supports impact assessment but not risk management. Finally, Kitchenham et al. [29], Alsanad et al. [30], and Pandey and Satyarthi [31] propose techniques to assist the requirements changes using UML models, ontologies, and traceability matrices, respectively. But, these works do not consider information from past projects, which can improve the accuracy of the estimations.

Our approach proposes the use of CBR together with association rules. CBR allows reuse experiences to aid decision-making while evaluating a new change request. The association rules have two well-defined goals: assisting in retrieving cases and creating solutions by the user. Regarding case retrieval, the system uses the association rules to define the weights of relevant attributes when calculating the similarity between cases. Association rules can also reveal attributes that tend to cause problems when associated. If similar past cases are not retrieved, the user can propose a strategy to evaluate the new request by analyzing this set of mined rules.

4. Research method

Our approach, shown in Fig. 1, was developed using a combination of the CBR cycle proposed by Aamodt and Plaza [32] with knowledge discovery proposed by Tan et al. [11]. Prentzas and Hatzilygeroudis [21] mentioned that the disadvantages or limitations of specific intelligent methods could be overcome or mitigated by their combination with other methods. CBR provides easy knowledge acquisition using past cases, modularity, incremental learning, and some explanatory facilities. ARM provides general and compact domain knowledge through rules and rule-based explanation facilities [21].

We have chosen to use ARM before starting the CBR cycle to verify if the attributes of the current CR are associated with attributes that generated problems in past cases. This verification is needed because not all change requests may have associated risks, and you do not need to run the CBR cycle. The attributes will be used to define the weights used in the CBR similarity calculation if such attributes that caused problems are associated with the current CR. ARM does not prepare the solution automatically, but it helps the stakeholder understand the attributes that can cause problems and build a solution.

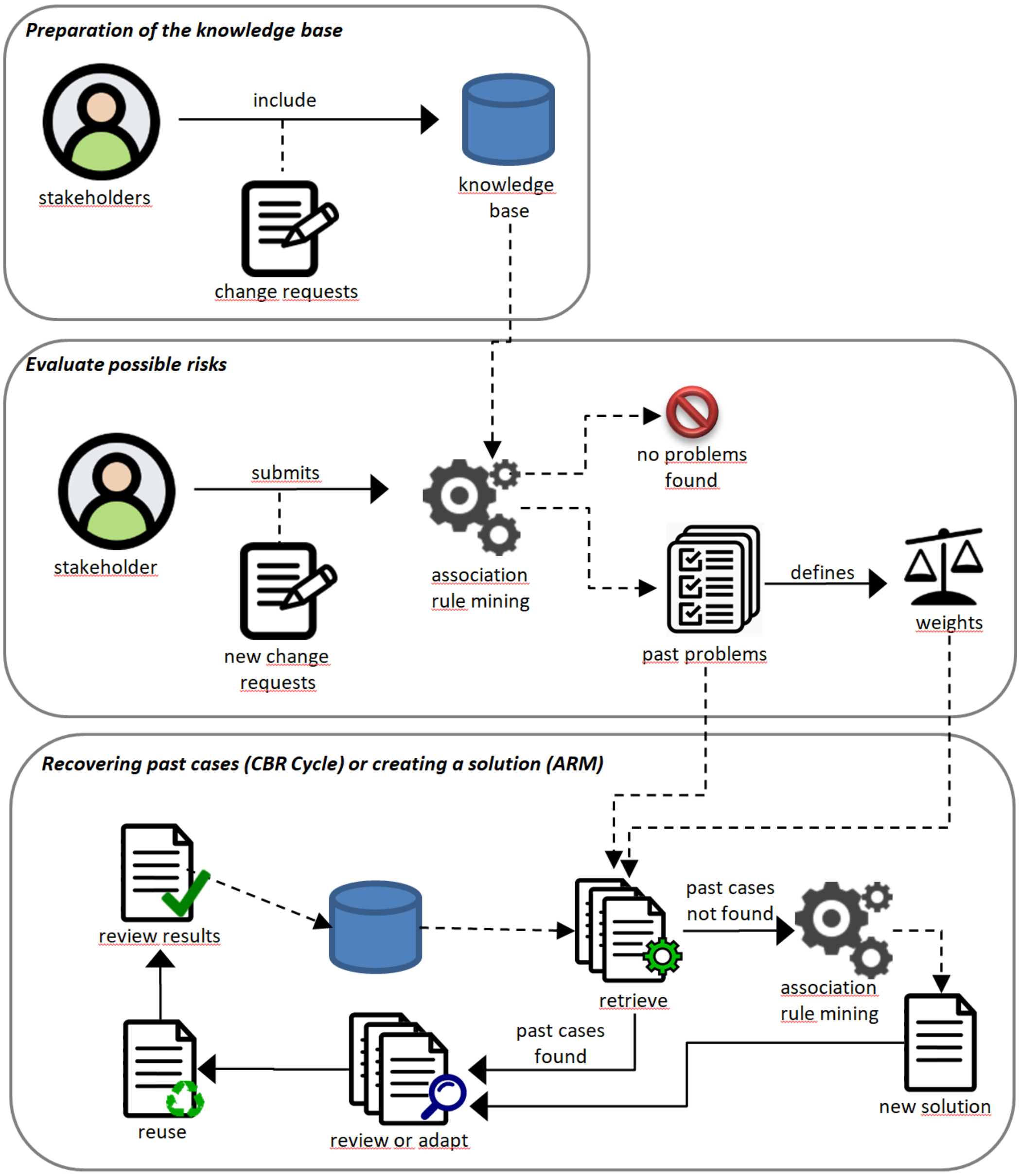

Fig. 1. Phases of the proposed approach

Therefore, our approach consists of the following phases:

1. Preparation of the knowledge base: change requests evaluated by the team are entered into the knowledge base. The data from these CR is prepared for use by the approach and is viewed as past cases;

2. Evaluating possible risks: possible risks of the current CR are evaluated by using the association of mining rules comparing the attributes of the CR with cases that generated problems in the past, extracting the data from the knowledge base using the Apriori algorithm;
3. Recovering past cases or creating a solution: if available in the knowledge base, then similar past cases are retrieved to be reused. The approach uses ARM to help the stakeholder create a solution if they are unavailable. After implementation, the stakeholder reviews the problems and solutions associated with the case and store them in the knowledge base.

4.1 Preparation of the knowledge base

The tool treats a change request as a case description created from a form containing the relevant attributes to be considered by the approach. A change request form has attributes and information for evaluating and implementing a change request. Explicit information and nonexplicit inferences should be considered. For example, project planning, the people involved, and the requirements affected impact the results of incorporating a change. Therefore, this data must also be available at the time of evaluation.

In ARM, this data is also necessary to identify the relationships that tend to generate consequences when they occur. The identified assumptions help the user assess whether a request has a low or high risk when implemented in the future based on the information entered in the form. Fig. 2 shows an example of a completed change request form and the class diagram used to represent the attributes and associations in the knowledge base.

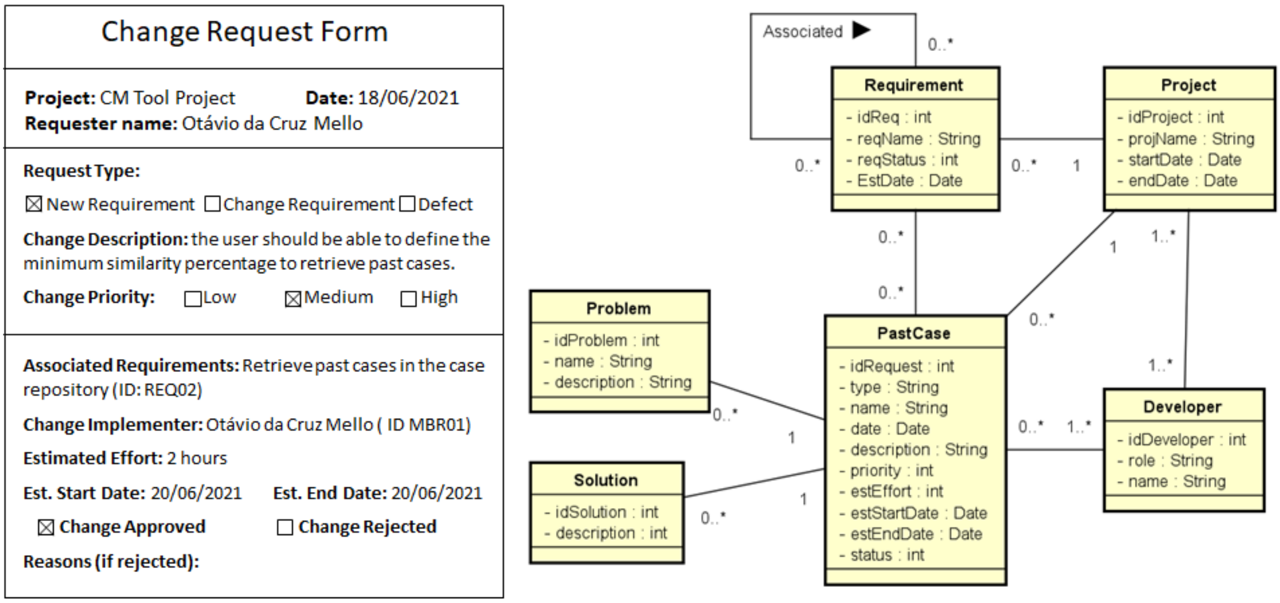

Fig. 2. A filled change request form example and Knowledge Base Class Diagram

4.2 Evaluating possible risks

The process begins when a stakeholder submits a new change request (Fig. 2). Then, the knowledge discovery process starts, retrieving associations of attributes of cases that have generated problems in the past by mining the data from the knowledge base using the Apriori algorithm. The retrieved premises are then compared with the data from the current CR to identify whether one or more rules apply to it. If at least one of the association attributes is not founded, then the approach considers that the rule is not related to the current CR. The full report of premises that could cause problems is also returned to the stakeholder for analysis, and their confidence value is used to weigh attributes in the search for past cases. A rule is commonly composed of two essential parts: a premise - an attribute or an association of attributes - and your consequence. Furthermore, confidence indicates the number of times the premise-consequence statements are valid.

After submitting a new CR, the approach will mine the association rules in the knowledge base. The rules that result in problems and have a confidence level of at least 50% are filtered and displayed to the user. In addition, those in which the premises are not found in the new CR or are not relevant to the analysis are discarded.

If the approach does not return premises to the CR, then there will likely be no obstacles in implementing this change. When this occurs, there is no need to follow the CBR cycle for recovery from past cases. In this case, it will be evaluated after implementing the change.

The attributes have their weight in the similarity function defined by the respective confidence value of the filtered rules. If no rule with a premise matches any of the attributes of the request, then this will have its weight set to a default value. After the weights are defined, the flow advances to the recovery of the most similar past cases.

4.3 Recovering past cases or creating a solution

After that, the CBR cycle begins, consisting of five activities: case retrieval, review of suggested solutions, reuse of solutions, review of results, and case retention.

The approach initially predetermines the weight value of each attribute based on the association rules found on the knowledge base in the previous phase. Then, the weight measures the significance of each attribute and is used in the similarity functions to retrieve the most similar past cases.

We use the value equality similarity function to retrieve the *priority*, *request type*, *associated requirements*, and *implementer* attributes. This function determines if the attributes have the same value. For the *estimated effort*, we assign the function *distance between values*, which calculates the similarity of the values by distance. The *change description* attribute requires a specific similarity function that identifies the frequency of keywords in one text and compares it to the frequency of those same words in another. We have used the *keywords frequency* similarity function.

The “*k*” most similar cases are retrieved and sorted according to their similarity degree. The value of “*k*” can be changed, but five cases are returned by default. The stakeholder is able to decide which case best suits the current situation. The problems identified in past cases and their causes are made available in a report along with the solution that was taken at the time. A case has three parts: *attributes*, *problems*, and *solutions*. *Attributes* describe relevant items related to the change: priority, estimated effort, request type, associated requirements, implementers, and description. *Problems* describe the problems identified in past experiences, and *solutions* have been adopted to solve the problems.

However, the approach proposes a solution based on ARM if similar past cases are not found. With the rules explored by the Apriori algorithm, the user can also identify possible problems that may arise while implementing the change based on the association of attributes. Based on this analysis, a solution can be created to predict risks associated with CR based on its attributes, even without a similar past case. Once defined, the process will follow the CBR flow.

After selecting a similar past case or creating a solution using association rules, the stakeholder can follow the same procedures used to solve the past case or adapt them to the new context. After that, the team implements the change request as previously defined.

Following the implementation of the change, the stakeholder should review the findings to ensure that the solution has effectively reduced the risks identified in the change evaluation. If the risks are meaningless, then they should not be taken off the case. Moreover, previously unforeseen problems may occur. In this situation, the stakeholder should combine the problems and the solution adopted in the case. After the reviews, the case must be inserted into the knowledge base to complement it for future requests.

5. Case study

We chose to conduct a case study to evaluate our intelligent approach to assist teams in performing a risk analysis of new change requests in a project. Thus, we selected a project that aims to develop a virtual tactical simulator for training military personnel in military operations that use an Artillery Saturation Rocket System in SIS-ASTROS project.

A case study is carried out to examine a single entity or phenomenon in a given time frame. Over time, the researcher collects detailed information about an actual project and documents the results [33]. Case studies help to assess the benefits of processes and tools and provide a cost effective way to ensure that process changes predict desired outcomes [29].

Wohlin [33] posited that a case study is more suitable if the effect of a process change is widespread. However, the effect of change can only be assessed at a high level of abstraction because process change includes smaller and more detailed changes throughout the development process [29].

Based on the literature [29][33][34], we defined the following steps to carry out the case study:

1. Conception and design: we define the objectives and design the case study;

2. Preparation for data collection: we define procedures for data collection;

3. Collection: we execute the approach with the support of the tool and collect the data;

4. Analysis and reporting of collected data: we analyze the collected data and report the results.

5.1 Conception and design

First, we defined the project in which the case study would be carried out, the objectives, the research hypotheses, and how to evaluate the hypotheses and the results obtained.

We carried out a case study on a project that started in May 2021, which has an estimated duration of 4 years and a development team of 30 people. This case study is a research project between the Federal University of Santa Maria (UFSM) and the Brazilian Army that aims to develop a tactical virtual simulator for training soldiers in operations related to using an Artillery Saturation Rocket System. Two members of the project's CCB took part in the evaluation. This project continues another project that started in December 2015 and lasted 5 years. The cases stored in the case base come from this first project.

The main objective is to determine whether the proposed approach supported by the tool can minimize the main difficulties and problems faced by change management professionals, mitigate their occurrence, or help to solve them. For this validation, we considered the challenges proposed by Andrew et al. [3] (described in Section 2.1) with a percentage greater than 10%. Therefore, our goal is to verify if our proposal helps the teams meet the following challenges: impact analysis, cost estimation, artifact document management, requirements traceability, requirements dependency, change conflicts with existing requirements, and time estimation.

To reach this goal, we evaluate whether the proposed approach, supported by the tool, provides the necessary support to solve the main challenges related to configuration management, based on the hypotheses listed below.

H1. Our proposal can help the project team to carry out a change impact analysis more effectively than when performed on an *ad-hoc* basis.

H2. Based on the returned cases, the team can estimate realistic costs and time to make the change.

H3. By associating requirements with changes, the approach allows considering requirements traceability, requirements dependency, and change conflicts with existing requirements when analyzing a change by the team.

H4. The approach allows managing artifact documents while maintaining a history of requirements changes over time.

5.2 Preparation for data collection

We have implemented a change management tool using the Java object-oriented programming language, the Weka API and jColibri libraries, and the Java DB relational database management system (Derby) to support the defined approach.

We initially enter the already evaluated and finalized change requests into the knowledge base. Then, we register the risks and solutions described in CR with the support of professionals involved in the change management activities of the project. In this activity, we inserted 25 cases of the SIS-ASTROS project in the case base. Fig. 2 depicts the class diagram representing the classes implemented in the tool.

In addition, we have separated 10 change requests to be evaluated during the data collection phase to verify that the tool and its base can return to the user past cases with coherent data about previous problems and solutions.

5.3 Collection

Two project developers used the tool to enter 10 CR during tool validation. In the case study description, we called them “users” as they played the system user role. For the evaluation of each CR, the user followed the steps described below (Fig. 3).

Initially, the user enters the data available in the change request form, shown in Fig. 2, into the evaluation tool and complements this data by informing the requirements and project members of the request (Fig. 3.1). This data is needed to identify past cases. From this data, the tool performs ARM to identify assumptions that created problems in the past. Next, the user checks those present in the CR (Fig. 3.2). The tool automatically assigns the weight for the attributes to be considered based on the validation rules (Fig. 3.3). The user may modify these values considering his experience and intuition.

The tool returns to the user the “*k*” cases most similar to the current case and the percentages of similarity assigned from the weights (Fig. 3.4). The user analyzes and selects the case he wants to reuse. When the case is selected, the tool informs the associated problems and solutions. It temporarily associates these problems with the new request (Fig. 3.5). Finally, after implementing the CR, the user records information about the change implementation in the tool, reporting the problems and solutions (Fig. 3.6).

5.4 Analysis and reporting of collected data

Runeson and Höst [34] noted that data collection through interviews is necessary for case studies. In this technique, the researcher asks a series of questions about the areas of interest in the case study. The dialog between the researcher and the interviewees is guided by a set of questions elaborated on the subjects of interest of the study [35]. In this case study, we used a semistructured interview. Initially, we prepared questions to verify whether the hypotheses were valid for the case. However, new questions emerged during the discussion and were included in the script.

During the validation, the project team developers considered the relevance of the results returned by the tool. Notably, the team had already implemented the CR used during validation. Therefore, the analysis can verify if the data returned by the tool were consistent with the actual implementation of the changes. The validation considered the relevance of the effort estimates, priority, problems, and the solutions documented in the past case to evaluate the current change request. Also notably, the problems encountered in past cases are significant sources of risk.

After entering all change requests, we interviewed the project team developers to verify if the hypotheses were valid for the case in question. Validation demonstrated that the approach helps in the evaluation of change requests. Many problems identified by retrieving past cases were also found during its implementation in the SIS-ASTROS project. We describe below some examples to demonstrate how the analysis was performed and how the results were obtained.

Fig. 3. Steps for evaluating a CR using the system

For the first change request used in the validation, the system retrieved the five most similar past cases, one where the similarity percentage exceeds 90% and others where it varies between 60% and 80%. The developers individually analyzed each case returned and selected the one that could be most useful for evaluating the current change request. In this example, the developers chose the most similar case because it has the same estimated effort as the new request, the same implementers, and the same change type (new requirement). In addition, the retrieved case description documented that much of the code had to be modified in implementing the change request.

Therefore, by comparing the information returned by the past case with that of the current change evaluation form, we saw that the CCB had identified this risk, which occurred in the change implementation. Therefore, the tool retrieved coherent and needed information for assessing the risks associated with the change. From another aspect, another problem was identified and described in the CR; it had inconsistencies with another previously defined requirement, requiring the team to acquire more information about the change from the customer. As this problem was not identified in the past case recovery, it had to be manually added. Situations such as these tend to occur in repositories that are still growing. As more past cases are stored, the information retrieved becomes more accurate and correct.

Another example was a change request to fix a defect related to viewing a simulator map. For this CR, similar past cases that, according to the team's developers, provided important information for evaluating the CR could also be retrieved. The most similar case reported difficulty in repetition as a problem. The tool returned two other less similar past cases that were not selected. The retry difficulty issue was associated with the new request. Upon further analysis, we confirmed that this problem occurred during the change implementation.

Past cases also helped to reject a change request. For example, in a change request, the customer requested a change in the teleport algorithm to allow teleporting vehicles to specific areas with dense vegetation. The past case retrieved reported the change's high complexity and that the algorithms had already been adjusted to allow for maximum vegetation density. Changes in these parameters could generate overlapping objects in the virtual world. Therefore, this information helps the team to reject a requested change without putting effort into its investigation.

Testing resulted in four possible scenarios: relevant cases were returned, no similar cases were returned, the problems returned did not satisfy the new request, or the most similar past case had no associated problems. Even with the small base, in only 10% of the cases tested, the system returned past cases that, according to the developers, were not relevant to the evaluation of the current request.

At the end of the validation, we interviewed the project developers to assess their perception of the validity of each hypothesis defined in the case study planning. Their considerations are described below.

Regarding H1, the developers agreed that the approach helps the project team to carry out a change impact analysis. They noted the importance of problems and solutions associated with the past case for identifying implementation risks and proposing responses. Developers could see that most of the issues reported in past cases occurred in implementing the change in the project.

In commenting on the impact analysis, the developers highlighted that the associations with the requirements help to identify the risks related to the requirement's complexity and source code quality. For example, complexity can lead to the need for additional time to understand current requirements, and poor source code quality can lead to refactoring (source code rewriting). When the project team evaluated the CRs, they did not identify the risk of requiring additional work owing to rewriting the source code. This association of the CR with the requirements allows for identifying this risk.

Regarding H2. The project developers agreed that the information from past cases returned by the tool helps estimate the time and cost of a change. According to the software engineering literature, using historical data is one of the most used techniques to perform estimation activities in software projects [36]. Past case retrieval considers the project member who made the change, the associated requirements, and the size of the change. These attributes are needed to improve the accuracy of estimates.

Regarding H3. The developers agreed that by associating requirements with change, the tool helps assess the impact of the change on other system requirements. In the tests, we can verify whether it was necessary to change other requirements not initially specified in the change request form if there are risks of implementing a change associated with a given requirement. Through past cases, developers could assess risks that requirements not described in the form but associated with the change may bring when implementing it. Traceability is also an important aspect to consider in the impact assessment, as noted in H1.

Regarding H4. The developers agreed that managing artifact documents is not the tool's purpose but maintaining a history of requirements changes over time. Most of the time, change request forms are not kept during the project and are discarded once the request is implemented. However, our approach stores these change requests in your case repository so that you can reuse them in the future in the CBR cycle. In this way, these documents will never be lost and can be viewed at any time by anyone, allowing the retrieval of the history of requirements changes.

Overall, the proposed approach based on CBR and ARM has the potential to solve seven of the 10 most frequent challenges encountered in managing change requirements.

5.5 Threats to validity

We performed a single case study for validation. We had to work with a limited set of change requests. Most of them, more specifically 25, were used to build an initial case base, and 10 additional cases were used during validation.

This number is relatively low, but only 10% of the time, the retrieved cases were inadequate to provide a solution for the new request. Therefore, this base needs to be supplemented with more past cases. In addition, the evaluation of the results obtained was carried out by two project developers and was a qualitative evaluation. In future works, we intend to improve our tool by adding more case studies on different projects.

One advantage of case studies is that they are easy to design. However, the disadvantages are that the results are difficult to generalize; it is possible to show the effects in typical situations evaluated.

6. Concluding remarks

As mentioned earlier, this study mainly aims to propose a change management approach that facilitates the risk analysis of a change request, providing information about past problems encountered in similar change requests and the solutions adopted. In this way, the approach helps teams to make better decisions and strategies when implementing a change.

Throughout this work, we present the selected techniques' basic concepts, the proposed approach, and the tool developed to support it. Finally, we validated the proposal to assess whether the approach and tool were adequate to solve challenges in change management.

The proposed approach was evaluated, considering the difficulties found in the literature. The approach had the potential to solve seven out of the 10 most frequent challenges of change management based on a deep analysis of each problem individually. From another aspect, the tool was evaluated by analyzing the results generated by a case base created using past change requests from the SIS-ASTROS project. This case base was built with the help of an expert from the project involved in change management activities.

The initial results showed that four different scenarios could occur: relevant cases were returned, no similar cases were returned, the problems returned did not satisfy the new request, or the most similar past case had no associated problems. However, only 10% of the cases failed to generate relevant results for the user.

After the tests, we interviewed the specialists to respond to hypotheses related to the change impact analysis, cost and time estimation, traceability, and dependency on previously defined requirements and documentation. They noted that the tool helped them to conduct change management activities and pointed out some considerations for improvement.

Based on the tests and the interview, the proposed approach can help to reduce the main problems in the area, and the support tool can provide logical results to identify possible implementation risks of the new change request.

We conclude from the results of this study that, although improvements are still needed, the usage of the proposed change management approach based on ARM and CBR can be beneficial. The risk analysis activity can be simplified for the user and consequently helps make decision-making easier.

Some limitations and difficulties were encountered during this research, particularly in its final stages. Acquiring data to create a case base for validation took considerable effort and time. As the project did not have many suitable change requests documented, we had to work with a relatively low number of change requests (25). Another issue we faced was the restricted number of professionals directly involved in change management activities in the project and their limited availability, causing the need to coordinate the testing and interview schedules.

Future works can improve this approach by proposing a solution to other issues in the change management area. In addition, future works can make changes to the support tool to bring more information, reports, and graphs to the user about the performance of the AI algorithms and improve the visual aspects of data representation to make their interpretation clearer when used.

This tool is also intended to be applied in other projects, and its performance can be analyzed over a longer time period with a more extensive case base. Thus, the results obtained can be evaluated in a practical environment, and therefore, implementation issues that may arise can be improved.

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