Vol. 14 | No. 1 | 2026

# International Journal of Information Systems and Project Management

ISSN:2182-7788
*Available online at ijispm.sciencesphere.org*

IJISPM



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

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

The journal serves academics, practitioners, chief information officers, project managers, consultants, and senior executives of organizations, establishing an effective communication channel between them.

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The journal content provides relevant information to researchers, practitioners, and organizations, and includes original qualitative or qualitative articles, as well as purely conceptual or theoretical articles. Due to the integrative and interdisciplinary nature of information systems and project management, the journal may publish articles from a number of other disciplines, including strategic management, psychology, organizational behavior, sociology, economics, among others. Articles are selected for publication based on their relevance, rigor, clarity, novelty, and contribution to further development and research.

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# EDITORIAL

It is our great pleasure to present to you the first issue of the 14th volume of IJISPM. In this issue, readers will find important contributions on ethical considerations, security and privacy, software development practices, hybrid project management, system implementation, outsourcing, and performance impacts.

## Questionable research practices in engineering research

Ana Alice Baptista, Filipe Pereira

*Misconduct in science is often associated with data fabrication, data falsification, and plagiarism. However, other practices are far more common. Questionable Research Practices (QRPs) are in the grey area between misconduct and responsible research conduct. The goal of this study was to investigate the estimated and self-admission prevalence of engineering researchers' engagement in QRPs. The authors administered a questionnaire containing 10 QRPs identified in the relevant literature. The questionnaire was adapted to include several categories: individual, research group, research center, and country. Results indicate that self-admission engagement in QRPs is generally higher than in similar studies. Also, respondents are more keen to estimate that others engage in QRPs than they or their research group do. Respondents admit engagement in all QRPs presented, such as failing to report all of a study´s dependent measures relevant to a finding, selectively reporting studies related to a specific finding that "worked," or even falsifying data. While some consider these practices unjustifiable, others justify them on the grounds of publication and time pressures.*

## Quality, security, and privacy assurance in software development: proactive integration or just workflow-slowing checkpoints?

Anne-Maarit Majanoja, Ville Leppänen

*In software development, the integration of assurance methodologies such as quality, security, and privacy practices is essential to producing high-quality, reliable, and compliant products. This paper investigates the adoption and effectiveness of these assurance practices within the daily operations of software development. Based on an industry survey of 88 software development professionals in Finland, this study examines the order and consistency with which developers apply assurance practices during projects, as well as the challenges they face in performing these tasks. The results show that while developers recognize the importance of assurance, many organizations still treat it as a separate, secondary activity rather than a core part of the development lifecycle. Key findings show that quality practices are more consistently integrated into daily operations compared to security and privacy measures, which tend to be reactive. The paper highlights the tension between agile practices, which promote flexibility and continuous improvement, and the more rigid, process-heavy nature of assurance tasks. The study underscores the need to shift both industry practices and educational approaches to fully embed assurance into software development.*

## Designing a fitting hybrid project management approach: a contingency perspective

Dagmar Silvius-Zuchi, Gilbert Silvius

*The hybrid approach in project management is now considered a leading approach, applied in many projects. However, the hybrid approach, defined as the combination of predictive and adaptive approaches, is still emerging, with several challenges and issues emerging from the literature. One problem is that the definition of hybrid as a combination of adaptive and predictive approaches leaves room for interpretation and variation. Hybrid is a spectrum of approaches to planning, controlling, organizing, leading, and executing a project, tailored to situational circumstances. It is this tailoring process that the study focuses on. Based on the criteria for assessing the fit of an approach, the study identified the following six hybrid approaches: 'Flexible predictive'; 'Tolerant predictive'; 'Predictable adaptive'; 'Adaptive light'; 'Integrated hybrid'; and 'Facilitated adaptive'. By applying a contingency approach to the design of a hybrid approach, the study aims to contribute to the further development of the understanding of hybrid project management.*

### Outsourced ERP system implementation success: The effects of client and vendor competences and their moderating roles

Boonlert Watjatrakul, Vimolluck Vatanapitukpong

*Previous research has overlooked how individual competence interacts with circumstances that could potentially affect the success of outsourced system implementation. This research leverages person-environment fit and expectation-disconfirmation theories to investigate how client and vendor competences, as external factors and moderators, along with partnership quality and task-technology fit, affect the performance and satisfaction in outsourced ERP system implementations. Data were collected via a survey of 414 ERP users from 12 companies and analyzed using PLS-SEM and slope analysis. The findings reveal that client and vendor competences shape task-technology fit and partnership quality, affecting performance and client satisfaction. Notably, task-technology fit does not always improve performance for highly competent clients, and satisfaction may decline when vendors are perceived as highly qualified, raising client expectations. A slight misalignment between tasks and technologies may even benefit highly skilled users. Furthermore, client satisfaction with ERP outsourcing is influenced by both performance outcomes and perceptions of vendor competence. This study provides practical guidance to enhance the success of outsourced system implementations.*

We want 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 resource for your continued work.

The Editor-in-Chief,

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João Varajão is a professor of information systems (IS) and project management (PM) at the University of Minho. He is also a researcher at the ALGORITMI/LASI research center. His main research interests are IS PM, IS Development, and IS Management (addressing PM success and the success of projects). Before joining academia, he worked as an Information Technology (IT)/IS consultant, project manager, IS analyst, and software developer, for private companies and public institutions. He has supervised over 140 MSc and PhD theses. He has published more than 300 works, including refereed journal articles, authored and edited books, book chapters, and conference presentations. He serves as editor-in-chief, associate editor, and editorial board member for international journals. He has served on numerous committees for international conferences. ORCID: 0000-0002-4303-3908

International Journal of Information Systems and Project Management (IJISPM)
2026, 14(1), e140101, DOI: 10.12821/ijispm140101

VIEWPOINT ARTICLE

# Questionable research practices in engineering research

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**Abstract**
Misconduct in science is often associated with data fabrication, data falsification, and plagiarism. However, other practices are far more frequent and prevalent. Questionable Research Practices (QRPs) are in the grey area between misconduct and responsible research conduct. The goal of this study was to investigate estimated and self-admission prevalence of engineering researchers' engagement in QRPs. We applied a survey through a questionnaire that used 10 QRPs identified in relevant literature. The questionnaire was adapted to include several categories: individual, research group, research center, and country. Results indicate that self-admission engagement in QRPs is generally higher than in similar studies. Also, respondents are more keen to estimate that others engage in QRPs than they or their research group do. Respondents admit engagement in all QRPs presented, such as failing to report all of a study´s dependent measures relevant to a finding, selectively reporting studies related to a specific finding that "worked," or even falsifying data. While some consider these practices unjustifiable, others justify them with publication and time pressures. More studies on the QRP engagement of engineering researchers are needed to get a more precise picture.

**Keywords**
ethics; scientific misconduct; questionable research practices; engineering.

Received: 13 November 2024 | Accepted: 22 April 2025

## 1. Introduction

The frequent appearance of news regarding scientific misconduct in recent times suggests an underlying, considerable problem. Scientific research has been founded on high ethical standards, but researchers still adhere to scientific misconduct, violating standard codes of conduct and ethical behavior in many ways. In this scope, misconduct could be of various types and due to various reasons: pressures to publish, competition for funding, tenure, and need for recognition and prestige, among others.

Scientific misconduct is often associated with behaviors considered by many to be the most serious: data fabrication, data falsification, and plagiarism (FFP). However, there are other practices that, while not considered as severe, are far more frequent and prevalent (Larsson et al., 2023) and can, therefore, cause more harm to science and society (Steneck, 2006). The Questionable Research Practices (QRPs) are in the "grey area of acceptable practice"(Fiedler & Schwarz, 2016; John et al., 2012). They are at the heart of competition between researchers and provide a significant advantage to those who adopt them, to the detriment of those who strictly conform to the rules of the game (John et al., 2012).

This study investigates estimated and self-admission prevalence of engineering researchers' engagement in Questionable Research Practices (QRP). Measuring the actual prevalence of these practices, as well as of any potentially reprehensible practices, is very difficult, if not impossible, because those who commit them do not always admit it, even under anonymity (Fanelli, 2009; John et al., 2012; Banks, Rogelberg, et al., 2016). Instead of studying self-admission, it is often decided to study the estimated prevalence, which can be studied in different ways, such as behavioral observations, sensitivity analysis, self-report surveys, or estimated prevalence surveys (Banks, Rogelberg, et al., 2016). Our study focused primarily on the prevalence estimated by researchers from all engineering research centers, the same research center, and the same research group. However, we also wanted to know what the researchers said about their adherence to these practices, thus shaping the self-admission prevalence. Often, not even the co-authors themselves are aware of QRPs' engagement. Therefore, self-admissions can identify involvement in QRPs that may not be identified otherwise (Banks, Rogelberg, et al., 2016).

Most studies on the prevalence of QRPs focus on the natural and social sciences (Banks, Rogelberg, et al., 2016), with some cross-domain studies. To the best of our knowledge, there are few studies in engineering. Engineering has its own specificities because it is a very vast and diverse domain of knowledge where a wide range of research methods and techniques are used (Ahmed, 2007; Horvath, 2008; Pedersen et al., 2000). We, therefore, see this study as exploratory as it "aims not to give conclusive results but to identify patterns, discover, describe, or gain insight about an issue, perform a tentative analysis, and lay the groundwork for future investigation (Swedberg, 2020 as cited in Haile, 2023). We have adapted an instrument used in other studies to contribute to form a first idea, albeit imprecise, about the general panorama in engineering. Subsequent studies can and should amplify and refine methods and techniques to obtain more accurate pictures. Our study can then contribute to a wake-up call for more studies.

The outline of this paper is as follows. Section 2 introduces and discusses state-of-the-art research on QRPs. Section 3 presents the methodology used in our study, followed by the presentation and discussion of results in Section 4. Finally, Section 5 presents the conclusions and future work.

## 2. Questionable Research Practices as forms of misconduct in science

Scientific research is subject to fraud, just like other human activities. Exceptional or singular scientific discoveries can result in the acknowledgment of the researchers and the accumulation of significant monetary resources and influence. While this is often a motivation for good research, occasionally it leads scientists to commit fraud (Koshland, 1987). In the codes of research conduct, it is common to find strong references to FFP, which many consider to be the most serious flaws. The National Science Foundation (USA), for instance, defines research misconduct as: "fabrication – making up data or results and recording or reporting them; falsification – manipulating research materials, equipment or processes, or changing or omitting data or results such that the research is not accurately represented in the research record; plagiarism – appropriation of another person's ideas, processes, results or words without giving appropriate credit" (Koshland, 1987). Steneck (2006) distinguishes research integrity from research ethics, since ethics has to do with "the critical study of the moral problems associated with or that arise in the course of pursuing research", and research integrity has to do with compliance with "professional standards" as outlined by competent institutions. The prevalence of FFP estimated by different authors varies, generally hovering below 5%, with authors placing it at 1% to 2% (Steneck, 2006; Banks, O'Boyle, et al., 2016; John et al., 2012) and others just above 4% (Gopalakrishna et al., 2022), which are very worrying figures for such serious practices. However, not all research integrity failures have to do with FFP. Many stem from the grey area of Questionable Research Practices.

The term "Questionable Research Practices" was coined by a committee of the USA Academy of Sciences in 1992 and defined as "actions that violate traditional values of the research enterprise and may be detrimental to the research process" (Steneck, 2006). Banks, O'Boyke and colleagues (2016) define them as "design, analytic, or reporting practices that have been *questioned* because of the potential for the practice to be employed to present biased evidence in favor of an assertion," which is a sufficiently broad definition (design, analytic, reporting), concerned with intentionality (potential purpose) and directed towards the result of engaging in QRPs (presenting biased evidence).

QRPs include "selectively reporting studies related to a specific finding that 'worked,'" "reporting an unexpected finding as having been predicted from the start" (Fiedler & Schwarz, 2016), duplicating or slicing articles, citation errors, failing to provide enough information about methods, or improper statistics and data analysis (Steneck, 2006). Although QRPs have been viewed somewhat benevolently in the past (Steneck, 2006), concern about them has been growing because of the impressive results of some studies that place them with an estimated prevalence far beyond what could be expected. Depending on the studies and calculation formulations, the estimated prevalence of QRPs varies greatly, with some studies putting the estimates well above 50 percent for some QRPs. This variability may be explained by, for example, whether or not the frequency of their occurrence is included in the calculation of the estimated prevalence (Bouter, 2024; Fiedler & Schwarz, 2016; John et al., 2012). In their literature review, Banks, Rogelberg and colleagues (2016) found very few studies that identified little or no evidence of involvement in QRP.

In a questionnaire survey, John and colleagues (2012) drew attention to the field of psychology, with results estimating the prevalence of certain QRPs at over 50%. Even self-admissions, which are usually expected to be low, are above 30% in four QRPs. Despite the authors' emphasis that "not all self-admissions represent scientific felonies" and that some respondents gave defensible reasons for engaging in those practices, the figures are still worrisome. Fiedler and Schwarz (2016) question part of the methodological procedures of John and colleagues' (2012) study, especially concerning the wording of the QRPs and the way to estimate prevalence. After performing some changes, they did a similar study in Germany, using two distinct ways of calculating the estimated prevalence. In this study, results on self-admission rates (having engaged in it in at least one study) continue to be very high, surpassing 40% in two QRPs and 30% in five QRPs, half of the QRPs. The estimated prevalence drops dramatically in the new formulations, but even so, the figures are worrying, being above 5% in half of the QRPs and around 10% in two of them. Agnoli and colleagues (2017) replicated John and colleagues' (2012) study. They found that for five QRPs self-admission rates were lower, and for two (QRP8 – Claiming to have predicted an unexpected result, and QRP10 – Falsifying data) were significantly higher. The estimated prevalence in this study were higher for eight QRPs, with two QRPs having estimated prevalence above 60%. Rabelo and colleagues (2020) replicated the same study in Brazil, resulting in higher self-admission rates for some QRPs and lower for others. The same happens for estimated prevalence. All these studies were done in the field of psychology. Latan and colleagues (2023) calculated self-admissions and estimated prevalence both with and without the occurrence frequency for business scholars in Indonesia. This study also found high rates of self-admission and estimated prevalence. An interesting result that Banks, Rogelberg and colleagues (2016) point out is that the reporting of QRPs in self-report surveys did not vary with academic rank.

Several other studies on QRPs have been carried out using different research methods. Banks, O'Boyle and colleagues (2016) used surveys and analysis of guidelines from 160 management journals. They found that a significant percentage of management researchers reported being instructed by reviewers or editors to engage in certain QRPs, such as selectively reporting hypotheses, excluding data post hoc, engaging in HARKing (hypothesizing after the results are known), and selectively including control variables. In another study reported in the same article, the authors found that some researchers disagreed some QRPs were not appropriate: "rounding down" a significance test (13% disagreement), selectively reporting hypotheses on the basis of whether they were statistically significant (23% disagreement), excluding data after looking at the impact of doing so on the results (21% disagreement), HARKing (25% disagreement) and selective inclusion or exclusion of control variables to achieve statistical significance (21% disagreement). Kepes and colleagues (2022) compared archival records of dissertations and subsequent journal articles to investigate QRPs, particularly HARKing. Using a sample of researchers from 10 top research-productive management programs, they compared hypotheses tested in dissertations to those tested in journal articles derived from those dissertations. The results show that "a greater percentage of supported dissertation hypotheses (28.3%) than unsupported dissertation hypotheses (10.4%) appeared in journal articles" and that "a substantial percentage of supported journal article hypotheses has no corresponding dissertation hypothesis," making it reasonable to suspect of HARKing. They also found that articles in the Top 8 journals had higher rates of potentially HARKed hypotheses, changing sample sizes, and covariates, indicating that results published in the most prestigious management journals may be less credible than those published in less prestigious journals. Among other results, these authors also found that dropping the hypothesis is not random; instead, it is systematic, as it "systematically suppresses small effect sizes and, therefore, biases the publicly available scientific evidence." Kaiser and colleagues (2022) analyzed data from a quantitative survey of Norwegian researchers about their attitudes and the prevalence of FFP and nine QRPs. The study revealed a low rate of self-reported FFP, but a considerable percentage of researchers reported involvement at least once in the following QRPs: create the impression of having consulted a source by copying other's citations – 20.7%, gift authorship – 11.3%, salami slicing – 8.4%, and to include irrelevant or unnecessary references in a publication to increase the citation frequency of a colleague, a research environment or a journal – 12.5%. Several authors indicate that open science practices (OSP) could mitigate adherence to QRPs. Still, Chin and colleagues (2023) study in the field of criminology found that a large majority of quantitative criminologists (87%) in the sample were found to have used QRPs while a nearly equal majority (89%) were found to have used open science practices (OSPs).

As stated before, adherence to a given QRP cannot always be classified as misconduct; in some cases, it may be justifiable and acceptable (Fiedler & Schwarz, 2016; John et al., 2012). Even if it is not readily justifiable, it may not be intentional: it can stem from misinformation about procedures and codes of conduct (Andrade, 2021), distraction, and carelessness, among others (Steneck, 2006). The literature points to various reasons for deliberate misconduct. These are the same as those for engagement in FFP: pressure to publish, pressure to raise funds, the unpopularity of "negative results," perverse incentives, promotions, tenure, among others (Banks, O'Boyle, et al., 2016; Banks, Rogelberg, et al., 2016; John et al., 2012; Makel et al., 2021; O'Boyle et al., 2017). As Bouter (2024) puts it, "what is good for the quality and reliability of research is not always good for a scholarly career."

Adherence to QRPs can significantly impact research and society. According to Steneck (2006), irresponsible behavior impacts research in four ways: "1) undermine the reliability of the research record, 2) weaken the trust colleagues have in one another and the trust the public has in researchers, 3) waste research funds, and 4) lead to decisions that cause public and/or personal harm." He argues that QRPs are even more impactful than FFPs, as they are more frequent and prevalent. The practice of QRP is especially worrying in health-related research, as it can cause serious harm to humans and other living beings if not, directly or indirectly, death. Authors who have resorted to the practice of HARKing (Hypothesizing After the Results are Known), for example, mislead others into assuming that the study is confirmatory rather than exploratory, which indicates that the results are confirmed and not the result of serendipity, and they can build on them. Another example is cherry-picking, where, for example, a researcher selects only the results that support their hypotheses, omitting the rest, or chooses to cite only articles that favor their views, misleading readers about the overall perspective (Andrade, 2021). The duplication of articles, a reporting QRP, for example, is considered by Steneck (2006) to be a waste of public money and effort (writing, peer review, editing) that could be invested with an adequate return for science and society. QRPs may "harm the development of theory, evidence-based practice and perceptions of the rigor and relevance of science" (Banks, Rogelberg, et al., 2016).

Science is built step by step, with successive additions to knowledge (contributions) by researchers, such as Sir Isaac Newton's famous "standing on the shoulders of giants." Trust in colleagues' professionalism and good faith is a cornerstone of this process. Quality control processes, such as peer review, identify and allow the elimination from the system of many research outputs (including articles) that are not of sufficient quality but cannot identify all of them. Many slip through the net of quality control, and the proof of this is the number of retractions that occur every year, many of which are in top journals. Research outputs obtained by engaging in QRPs and passing the quality control sieve are seen as good by other researchers, who use them to build new research, wasting their time and stalling scientific progress (John et al., 2012).

It is essential to combat adherence to QRPs because of their highly harmful short- and long-term effects. Relying on the virtuosity of researchers is not the solution. Several studies have already identified the causes of undesirable behavior in research. Now they need to be mitigated and, if possible, canceled. To this end, several authors advocate open science practices as the pre-registration of the research (Bouter, 2024; Peels & Bouter, 2023; Kepes et al., 2022). The requirement to deposit raw data in a data repository such as Zenodo can also help mitigate some QRPs related to data analysis. Other measures could include greater dissemination and training on codes of conduct in research, adopting dissuasive policies, reviewing procedures for obtaining research funding and career progression, improving the quality of peer review and reforming research assessment (Bouter, 2024; Andrade, 2021; Banks, O'Boyle, et al., 2016; Banks, Rogelberg, et al., 2016; Makel et al., 2021; Sørensen et al., 2021).

## 3. Methodological procedures

We conducted a questionnaire survey based on the 10 QRPs used by John and colleagues (2012) and later modified by Fiedler and Schwarz (2016). Anonymous surveys can be a good way of more reliably identifying the engagement in QRPs of an individual or people they know (Fiedler & Schwarz, 2016), their motives, and the potentially associated external pressures they face (Banks, Rogelberg, et al., 2016). The QRPs are the following:

QRP1 – Failing to report all of a study's dependent measures that are relevant for a finding.

QRP2 – Collect more data in order to render non-significant results significant.

QRP3 – Failing to report all of a study's conditions that are relevant for a finding

QRP4 – Stopping collecting data earlier than planned because the expected result concerning a specific finding were already obtained.

QRP5 – 'Rounding off' a p value (e.g. reporting that a p value of .054 is less than .05).

QRP6 – Selectively reporting studies related to a specific finding that "worked."

QRP7 – Deciding whether to exclude data after looking at the impact of doing so on the desired results.

QRP8 – Reporting an unexpected finding as having been predicted from the start.

QRP9 – In a paper, claiming that results are unaffected by demographic variables (e.g. gender) although one is actually unsure (or knows that they do).

QRP10 – Falsifying data.

QRPs were written in Portuguese, followed by their original English version in a smaller font size. For each QRP, respondents were asked to respond to the question, "What is your estimate of the prevalence (in %) of this practice, across all hypothesis tests conducted by ..." (Fiedler & Schwarz, 2016). Unlike other studies that only asked about the respondent and all researchers, we decided to ask respondents to enter information about the following categories:

- All engineering researchers from Portuguese research centers;

- All engineering researchers from their research center;

- All engineering researchers from their research group;

- The respondent.

With the following response options for the estimated prevalence: 0%; ]0% - 20%], ]20% - 40%], ]40% - 60%], ]60% - 80%], ]80% - 100%[, 100%. Then, still, for each QRP, the following additional question was asked: In your opinion, what circumstances can justify this practice?

Demographic questions included age, number of years as a researcher, gender, country of research, and scientific field of research. In this respect, we considered the scientific fields of engineering that the Portuguese Foundation for Science and Technology (FCT) recognizes for project submissions. Four generic fields were added so that non-engineering respondents could identify their field, minimizing the risk of being mistaken for engineering researchers. Two more options have been added to include all the possibilities: (1) another engineering and (2) another area.

The first version of the questionnaire was tested and validated with five respondents between 22 and 28 November 2019. The validation questionnaire was made available online, and respondents were asked to answer as if they were using the final version of the questionnaire so that their answers could be used if the validation resulted in minor changes (typos and minor formal issues). According to the respondents to the validation questionnaire, the QRP questionnaire was straightforward, and no changes were suggested. For this reason, there were no changes to the questionnaire, and the version applied was the first and, so far, only version of that questionnaire.

The questionnaire was made available on 15 January 2020 and was open continuously for several months. It was disseminated in various engineering research centers at several Portuguese universities, and respondents were asked to pass it on to colleagues. Engineering PhD students were also asked to complete the questionnaire and pass it on to colleagues.

The questionnaire had 72 answers, but three were empty, so 69 researchers answered it. Eight of these worked in fields other than engineering, so they were removed from the sample, leaving 61 answers. Two of these answers were the same, so one of them was eliminated, leaving 60 valid answers. The results were exported to Microsoft Excel, where they were aggregated for the analysis. The graphs were done using Apple Numbers. For clarity of reading and analysis, for each QRP we have presented the answers in two graphs, the first relating to all the engineering research centers and the respondent's research center, and the second relating to the respondent's research group and the respondent (self-admission). We used the same scale for each pair of graphs to make it easier to compare them. In self-admission, we prefer to use the term "prevalence" rather than "rate" because we believe it is infrequent for someone to rigorously count their past involvement in QRPs to report it in a questionnaire.

The questionnaire, the validation and contact forms, the questionnaire results, and the validation results were made openly available at: https://doi.org/10.5281/zenodo.15199607

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2026, 14(1), e140101, DOI: 10.12821/ijispm140101

## 4. Results

Most respondents are between 24 and 35 years old, 55% (33) are male, and the remaining 45% (27) are female. Most respondents have worked as researchers for up to 10 years, and all carry out research in Portugal (Fig. 1).

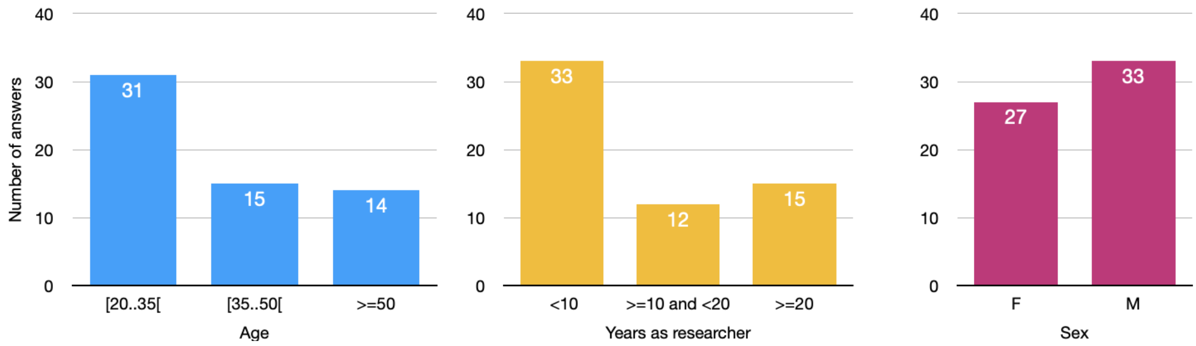


Fig. 1. Demographic data of the respondents

Of all the engineering fields considered, the one with the most respondents, by far, is Electrical Engineering and Computer Engineering (45%). Mechanical Engineering and Engineering Systems comprise 13% of the answers, and Bioengineering, Biotechnology, and Biochemistry comprise 12%. Materials Science and Engineering make up 10%, with all other options accounting for 7% each (Fig. 2).

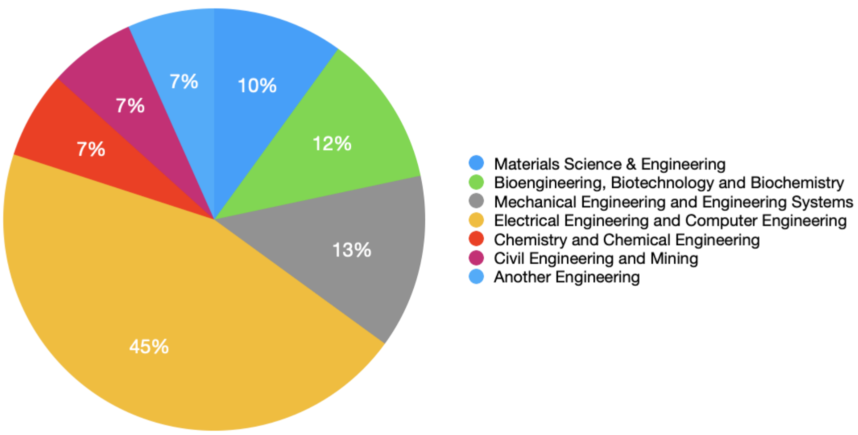


Fig. 2. Distribution of the respondents by knowledge domain.

Regarding QRP 1 - Failing to report all of a study´s dependent measures relevant to a finding, 22 respondents (36.7%) report having never been engaged in this QRP, leaving 63.3% of researchers admitting to having engaged in it in at least one study (prevalence greater than 0%) (Fig. 3). This self-admission prevalence is close to the findings of John and colleagues (2012) (63.4%) and higher than the findings of Agnoli and colleagues (2017) (47.9%) and Latan and colleagues (2023) (57.63%).

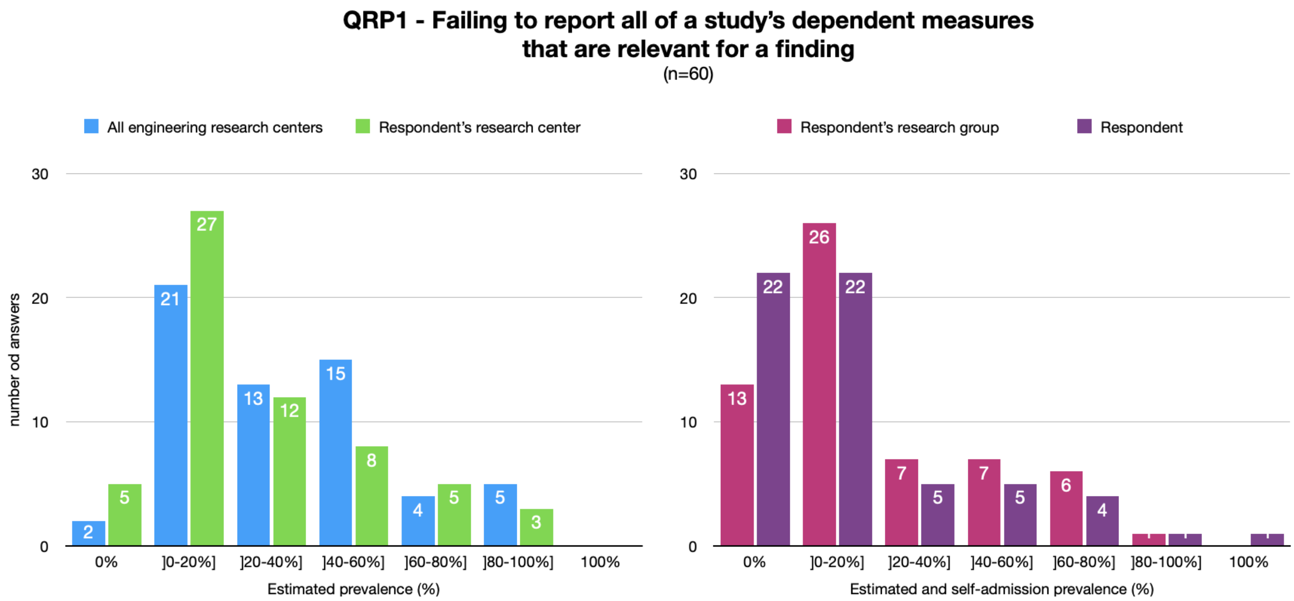


Fig. 3. Estimated and self-admission prevalence of QRP1.

The mode class of the estimated prevalence for engaging in QRP1 is ]0%-20%] for all categories and also 0% for self-admission. The median is situated in the ]0%-20%] range for all categories except all engineering research centers, which is ]20%-40%] (Table 1).

The estimated prevalence for QRP1 by John and colleagues (2012) is 59.03%, by Agnoli and colleagues (2017) is 58.51%, and by Latan and colleagues (2023) is 61.41%.

Table 1 . Mode and median classes for the estimated prevalence of QRP1 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0-20%] | ]20%-40%] |
| Respondent's research center | ]0-20%] | ]0-20%] |
| Respondent's research group | ]0-20%] | ]0-20%] |
| Respondent | 0%, ]0-20%] | ]0-20%] |

Analysing the answers to the open question (what circumstances could justify this practice?), we find that most answers relate to the pressure to publish something different and relevant in the area and the tight deadlines. Lack of time and space is also referred to: "Limits on space in publications; less important relevant details end up being cut." Respondents also refer to the protection of results for future research: "Fear of exploitation by research groups, with more human and technical capabilities," or "Try to protect some adjustments so that other centres do not overtake them." Other justifications are innocence, ignorance, competitiveness, convenience, inexperience, and uncertainty about the relevance of specific data for the research. There are still those (8.3%) who believe that nothing justifies this practice.

International Journal of Information Systems and Project Management (IJISPM)
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Concerning QRP2 - Collect more data to render non-significant results significant; when asked about the prevalence of this practice, self-admission amounts to 37 (61.7%), with 5 (8.3%) admitting a prevalence of more than 80% on their works (Fig. 4). This self-admission prevalence is higher than the findings of John and colleagues (2012) (55.9%), Agnoli and colleagues (2017) (53.2%), and Latan and colleagues (2023) (59.32%).

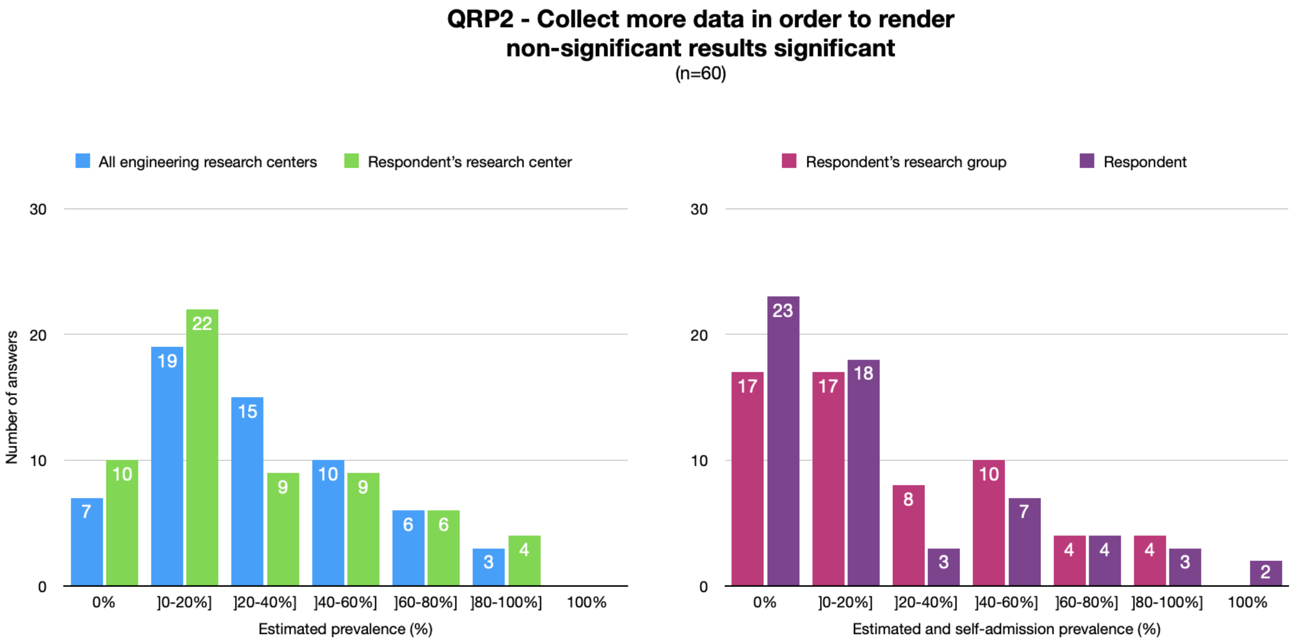


Fig. 4. Estimated and self-admission prevalences of QRP2.

The mode class of the estimated prevalence for engaging in QRP2 is 0% in self-admission and the respondent's research center and ]0%-20%] also for the latter and remaining categories. The median is situated in the ]0%-20%] range for all categories except all engineering research centers in which it is ]20%-40%] (Table 2). The estimated prevalence for QRP2 by John and colleagues (2012) is 61.01%, by Agnoli and colleagues (2017) is 63.18%, and by Latan and colleagues (2023) is 63.14%.

Table 2. Mode and median classes for the estimated prevalence of QRP2 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0-20%] | ]20%-40%] |
| Respondent's research center | ]0-20%] | ]0-20%] |
| Respondent's research group | 0%, ]0-20%] | ]0-20%] |
| Respondent | 0% | ]0-20%] |

Regarding the open question, some respondents do not accept a possible justification, and some have said this is fraud and a lack of professionalism. Some respondents also justify this practice with the need to obtain positive results, saying, “When results need to be confirmed” or “Need to make the work publishable.”

However, some respondents draw attention to the sample size (without worrying about changing it throughout the research process). One says “Collecting more data does not seem a way of biasing the results, but rather a way of making the conclusions more solid. If increasing the sample size changes the conclusions, these should be the more sustained conclusions since more cases support them.” Another argues that “Several statistical methods require a minimum cardinality. As such, collecting more data helps make these methods applicable and reduces the weight that possible outliers may have.”

Another respondent says, “I don't understand; if anything happens, it's the opposite,” possibly meaning that they do not know about cases where the sample size is increased during the research process but may know about cases where the sample is manipulated by reducing it in some way.

Analysing the answers given to QRP3- Failing to report all of the study´s conditions that are relevant to a finding, when asked about the prevalence of this practice, 36.7% of respondents admit to having done so with a prevalence of over 0 to 20%, and 34 (56.7%) admit to having resort to this practice in at least one study (Fig. 5). This self-admission prevalence is higher than the findings of John and colleagues (2012) (27.7%), Agnoli and colleagues (2017) (16.4%), and Latan and colleagues (2023) (42.8%).

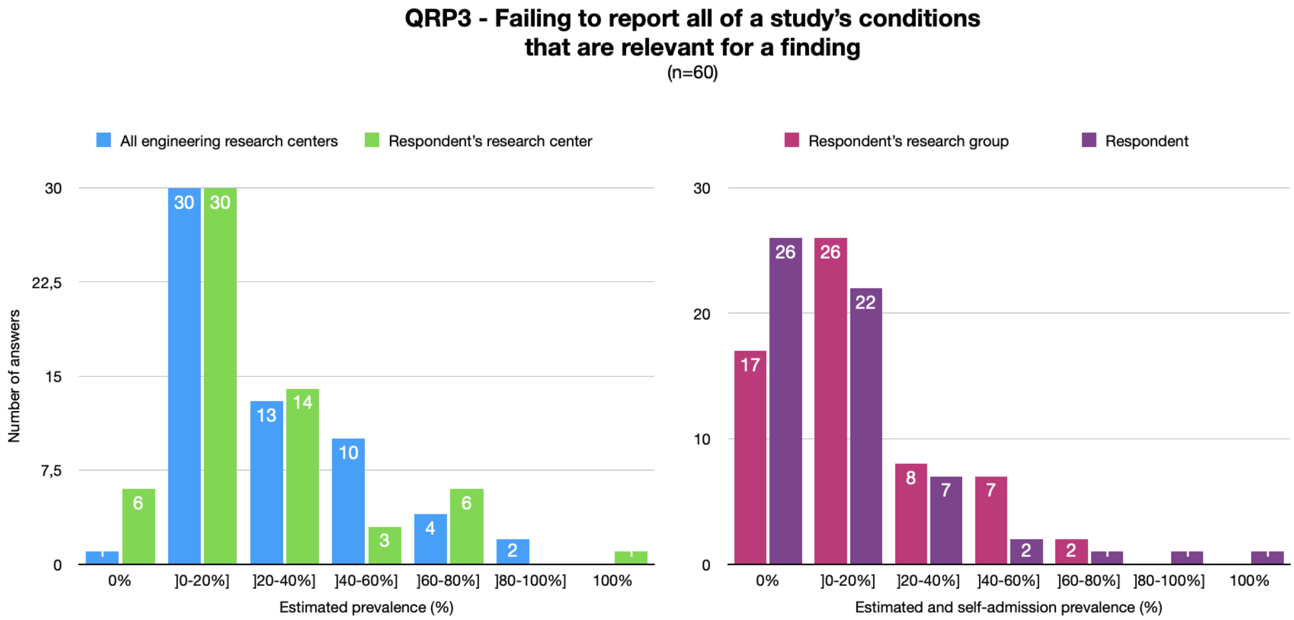


Fig. 5. Estimated and self-admission prevalences of QRP3

The mode class of the estimated prevalence for engaging in QRP3 is 0% in self-admission and ]0%-20%] for the remaining categories. The median is situated in the ]0%-20%] range for all categories (Table 3). The estimated prevalence for QRP3 by John and colleagues (2012) is 35.64%, by Agnoli and colleagues (2017) is 40.80%, and by Latan and colleagues (2023) is 44.59%.

Table 3. Mode and median classes for the estimated prevalence of QRP3 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0-20%] | ]0-20%] |
| Respondent's research center | ]0-20%] | ]0-20%] |
| Respondent's research group | ]0-20%] | ]0-20%] |
| Respondent | 0% | ]0-20%] |

Proceeding with the analysis of the reasons that could lead researchers to this practice, some justifications that come up are the lack of: experience, time and space (in articles), resources, proficiency in methods, and accuracy. Some refer to forgetting as justification. Some respondents justify this practice with confidentiality issues, or even "To avoid the reproducibility of published tests. To keep 'trade secrets'" or, again, "Fear of exploitation by research groups with more human and technical capacities." As a plausible justification, one respondent says, "Sometimes these conditions aren't reported because the trial didn't go so well, but you still want to publish the study because you are convinced that if the trial had gone well the results would have been as expected." Another respondent says, "Lack of availability of varied test scenarios does not allow complete conclusions to be drawn, so possible features are extrapolated from a single scenario, but it is generally claimed that the method is generalist."

About QRP4 - Stopping collecting data earlier than planned because the expected result concerning a specific finding was obtained; when asked about the prevalence of this practice, 43.3% of respondents claim never having resorted to this practice, leaving 56.7% admitting to having engaged in it in at least one study (Fig. 6). This self-admission prevalence is much higher than the findings of John and colleagues (2012) (15.6%), Agnoli and colleagues (2017) (10.4%) and Latan and colleagues (2023) (23.94%).

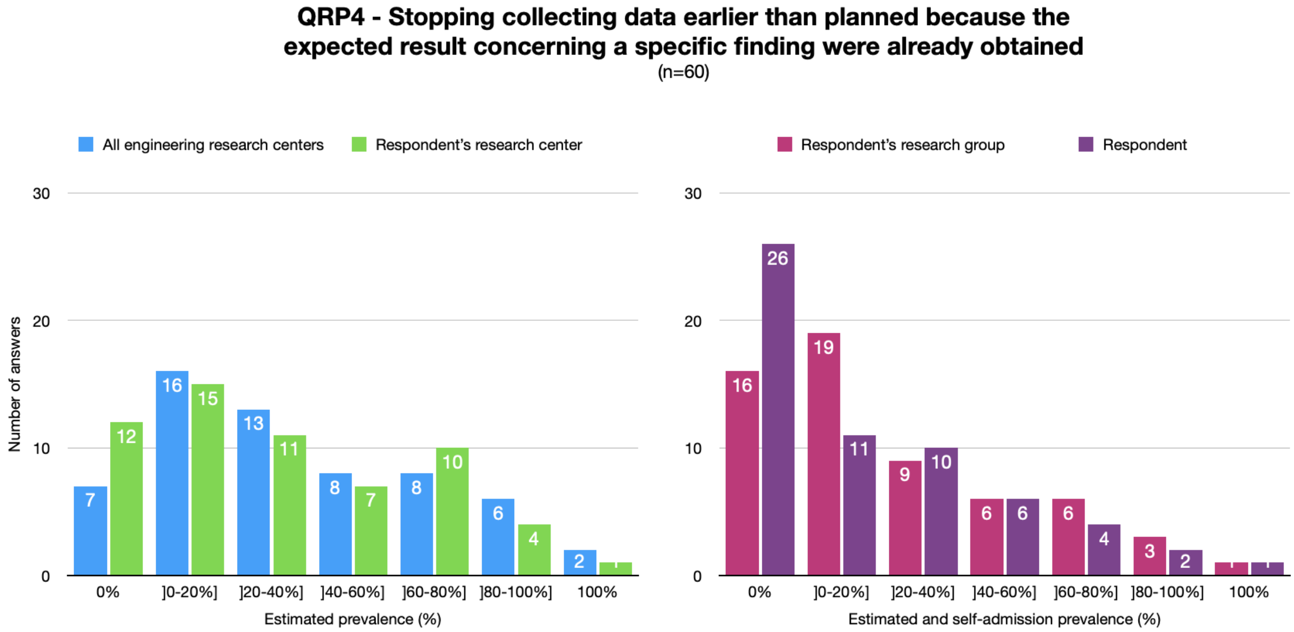


Fig. 6. Estimated and self-admission prevalences of QRP4

The mode class of the estimated prevalence for engaging in QRP4 is 0% in self-admission and ]0%-20%] for the remaining categories. The median is situated in the ]0%-20%] class for self-admission and the respondent's research group and in ]20%-40%] for the two remaining categories (Table 4). The estimated prevalence for QRP4 by John and colleagues (2012) is 38.98%, by Agnoli and colleagues (2017) is 37.30%, and by Latan and colleagues (2023) is 44.56%.

Table 4 . Mode and median classes for the estimated prevalence of QRP4 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0-20%] | ]20%-40%] |
| Respondent's research center | ]0-20%] | ]20%-40%] |
| Respondent's research group | ]0-20%] | ]0-20%] |
| Respondent | 0% | ]0-20%] |

Regarding the open question, most respondents mention that a possible justification for this practice might be the need to finish the study as soon as possible, deadlines, lack of time, and lack of resources. Some claim that "It is not repeated after the positive result because it is expensive," and "to save money."

There are other justifications for adopting this practice. One respondent says, "Sometimes in vitro or in vivo tests don't justify continuing the study. This avoids animal sacrifice and costs". Another respondent claims, "There are many studies that are already planned to be finalized if the first trials turn out as expected." Another one says "Even if the expected result has already been obtained, the experience constitutes further proof. In fact, the conditions of two experiments are always different, even if only minimally." Yet another respondent argues the question is not clear enough as "there are many circumstances in which you can effectively end a study as soon as you find the desired result, such as finding a counterexample to a conjecture."

Regarding QRP5 "Round" a p-value (for example, reporting that a p-value of 0.054 is less than 0.05), when asked about the prevalence of this practice, the majority of respondents (58.3%) claim never to have resorted to it, leaving 41.7% to admit having engaged in it in at least one study (Fig. 7). This self-admission prevalence is much higher than the findings of John and colleagues (2012) (22.0%), Agnoli and colleagues (2017) (22.2%) and Latan and colleagues (2023) (22.67%).

Over one-fourth of respondents (26.7%) estimate the prevalence of this QRP for researchers from all research centres to be between over 0 and 20%. In comparison, 36.7% believe this to be the prevalence of resorting to this practice in their research centre.

The mode class of the estimated prevalence for engaging in QRP5 is 0% in self-admission and in the respondent's research groups and ]0%-20%] for the remaining categories. The median is situated in the ]0%-20%] class for all categories except self-admission, where it is 0% (Table 5). The estimated prevalence for QRP5 by John and colleagues (2012) is 40.55%, by Agnoli and colleagues (2017) is 46.79%, and by Latan and colleagues (2023) is 43.63%.

Regarding the open question, over 20% of the respondents consider the use of this practice to be unjustifiable. Others attribute it to imprecision or lack of scientific rigor, lack of ethics, ignorance, or just intentionally including a result in a specific category (other than the real category).

Some refer to the pressure to obtain results. One respondent claims, "In publications that require the sharing of data used to apply statistical methods, this practice is easily detected. Likewise, the absence of a statistically valid result can also be of interest, provided it is argued. Over-utilizing the application of statistical tools in studies to extract statistically valid

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results that are difficult to interpret is a fairly common practice, and it is what motivates this type of practice. In my opinion, there is no justification for it". Like in other QRPs, some respondents claim that the pressure to publish or to obtain funds can be a justification for this practice.

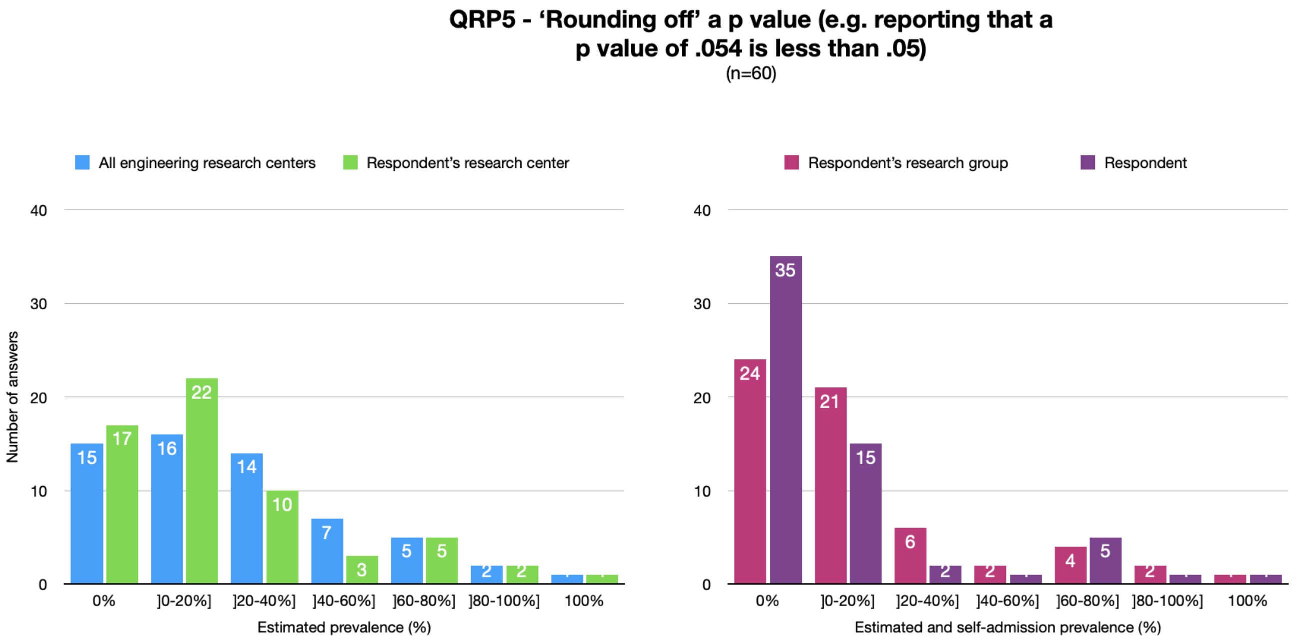


Fig. 7. Estimated and self-admission prevalences of QRP5

Table 5 . Mode and median classes for the estimated prevalence of QRP5 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0-20%] | ]0-20%] |
| Respondent's research center | ]0-20%] | ]0-20%] |
| Respondent's research group | 0% | ]0-20%] |
| Respondent | 0% | 0% |

Concerning QRP6 - Selectively reporting studies related to a specific finding that "worked," when asked about the prevalence of this practice, a large proportion of respondents (35.0%) say they have never resorted to this practice, leaving 65% of researchers having engaged in it in at least one study (Fig. 8). As with other QRPs, self-admission in this practice has a higher prevalence than in John and colleagues (2012) (45.8%), Agnoli and colleagues (2017) (40.1%) and Latan and colleagues (2023) (49.15%).

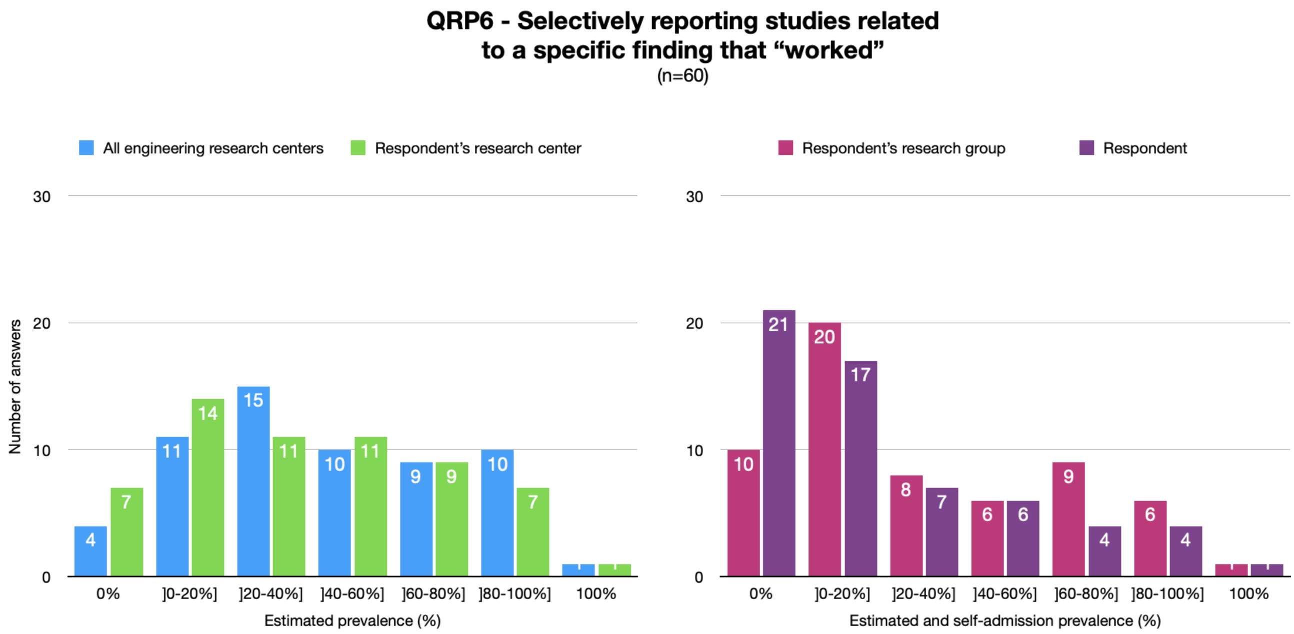


Fig. 8. Estimated and self-admission prevalences of QRP6

The mode class of the estimated prevalence for engaging in QRP6 is 0% in self-admission, ]0%-20%] in the respondent's research group and center, and ]20%-40%] for all engineering research centers. The median is situated in the ]20%-40%] class for all and the respondent's research centers and in the ]0%-20%] class for the respondent's research group and self-admission (Table 6). The estimated prevalence for QRP6 by John and colleagues (2012) is 59.90%, by Agnoli and colleagues (2017) is 65.82%, and by Latan and colleagues (2023) is 60.52%.

Table 6. Mode and median classes for the estimated prevalence of QRP6 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]20%-40%] | ]20%-40%] |
| Respondent's research center | ]0-20%] | ]20%-40%] |
| Respondent's research group | ]0-20%] | ]0-20%] |
| Respondent | 0% | ]0-20%] |

Regarding what could justify this practice, some respondents claim nothing justifies it (10%). As with other QRPs, some justifications center around the need to present interesting results for publication. One respondent calls it "Strengthening the robustness of the results." Another argues, "Sometimes results are presented selectively because they need more substantiation or because it is impossible to put all the information in one article." Still, another respondent says, "Publications must be scientifically consistent. Reporting cases that discredit work done decreases the chances of publication."

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There are, however, other perspectives. One respondent claims, "The practice of cherry picking is quite common and strongly related to the bias that is typical of a researcher. In my opinion, it is perfectly justified if this practice is not intended to show a trend (trends that should only be shown through a meta-analysis) but rather to list favorable examples. Trying to draw an inference in this way is a fallacy." Another respondent argues: "Again, I think it has to do with the fact that researchers think that results that don't support the hypotheses tested are 'bad results.' I think this is a huge mistake because the fact that a certain method doesn't work for a given purpose is a result of as much interest and relevance as the one that does."

Regarding QRP7 - Decide if you want to exclude data after analyzing the impact of this on the desired results; when asked about the prevalence of this practice, a large proportion of respondents (36.7%) say they have never resorted to it, leaving 63.3% admitting to having engaged in it in at least one study (Fig. 9). As with other QRPs, self-admission in this practice has a higher prevalence than in John and colleagues (2012) (38.2%), Agnoli and colleagues (2017) (39.7%) and Latan and colleagues (2023) (43.43%)

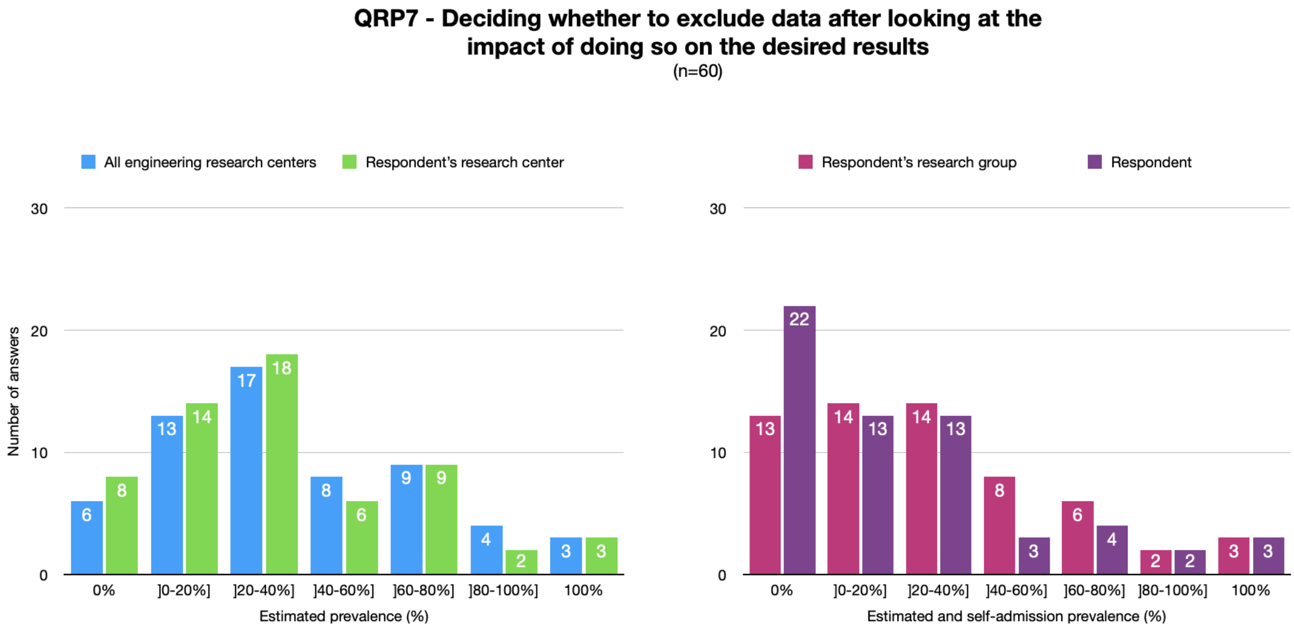


Fig. 9. Estimated and self-admission prevalences of QRP7

Over a quarter of the respondents (28.3%) estimate that the prevalence of this practice among researchers from all centres may be between 20 and 40%. The mode class of the estimated prevalence for engaging in QRP7 is 0% in self-admission; the respondent's research group has two modes, ]0-20%] and ]20%-40%], and ]20%-40%] for the remaining categories. The median is situated in the ]20%-40%] class for all categories except self-admission, where it is ]0%-20%] (Table 7). The estimated prevalence for QRP7 by John and colleagues (2012) is 45.24%, by Agnoli and colleagues (2017) is 55.91%, and by Latan and colleagues (2023) is 50.35%.

Table 7. Mode and median classes for the estimated prevalence of QRP7 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]20%-40%] | ]20%-40%] |
| Respondent's research center | ]20%-40%] | ]20%-40%] |
| Respondent's research group | ]0-20%], ]20%-40%] | ]20%-40%] |
| Respondent | 0% | ]0-20%] |

Regarding the open question, some respondents (13.3%) related this QRP to the presence of outliers. For example, one respondent asks: "Is 'cleaning' outliers a bad practice? That's how I interpret this question. It depends greatly on the type of study you want to do". Another respondent said this QRP was justified "in cases of (severe) outliers so as not to influence averages, etc.". Convenience due to restrictions on the size of articles is also a justification, with one respondent saying, "Either it is non-relevant data with no impact that compromises the size of the article submission, or some use this method to polish outliers in the results."

Another respondent argues that "Data exclusion is a common practice. If there is space and interest in doing so, I always try to present the data exclusion criteria that serve as a legitimate basis for excluding certain data (outliers, erroneous data, flaws in the execution of experimental protocols, etc.). The discussion of this type of practice is, in my opinion, welcome in a publication, even though space and time are rarely available." Another respondent argues, "By performing certain statistics/controls, there are adequate scientific methods to exclude 'outliers,' which should always be performed to understand the origin of the variability of the data." However, another respondent says, "It is still the same question. Biasing the results towards what you think are 'good results' and 'good conclusions.' All results should be reported because they all help future work in the field."

Regarding QRP8 - Reporting an unexpected finding as having been predicted from the start, when asked about the prevalence of this practice, many respondents (48.3%) claim never to have resorted to it, leaving 51.7% admitting to having resorted to this QRP in at least one study (Fig. 10). As with other QRPs, self-admission in QRP8 has a higher prevalence than in John and colleagues (2012) (27.0%), Agnoli and colleagues (2017) (37.4%) and Latan and colleagues (2023) (37.29%).

When asked about researchers from all research centres, one-third of respondents (35.0%) estimate that the prevalence of this practice may be between over 0 and 20%. The mode class of the estimated prevalence for engaging in QRP8 is 0% in self-admission and ]0-20%] for the remaining categories. The median is situated in the ]0%-20%] class for all categories except all engineering research centres where it is ]20%-40%] (Table 8). The estimated prevalence for QRP8 by John and colleagues (2012) is 47.73%, by Agnoli and colleagues (2017) is 59.41%, and by Latan and colleagues (2023) is 50.98%.

Once again, researchers present the pressure to publish as a possible justification. One respondent says, "This practice is justified by the ease of finding or disseminating a work. Serendipity can and should be mentioned in the text, but in the case of the abstract and title, it is understandable that the finding is included as expected."

Some refer to scientific pride or willingness to demonstrate competence as potential reasons. One respondent claims, "You also need to look competent. Reporting accidents diminishes the contribution, unfortunately. It did not used to be like that. All science starts from an initial fluke." In the opposite direction, probably because they work on another engineering topic, another respondent says, "In engineering, discovery is valued, so there is no incentive for this practice." Corroborating this opinion, another respondent says, "I do not see much 'advantage' in saying that you have been looking for a long time for a certain result that you found by chance."

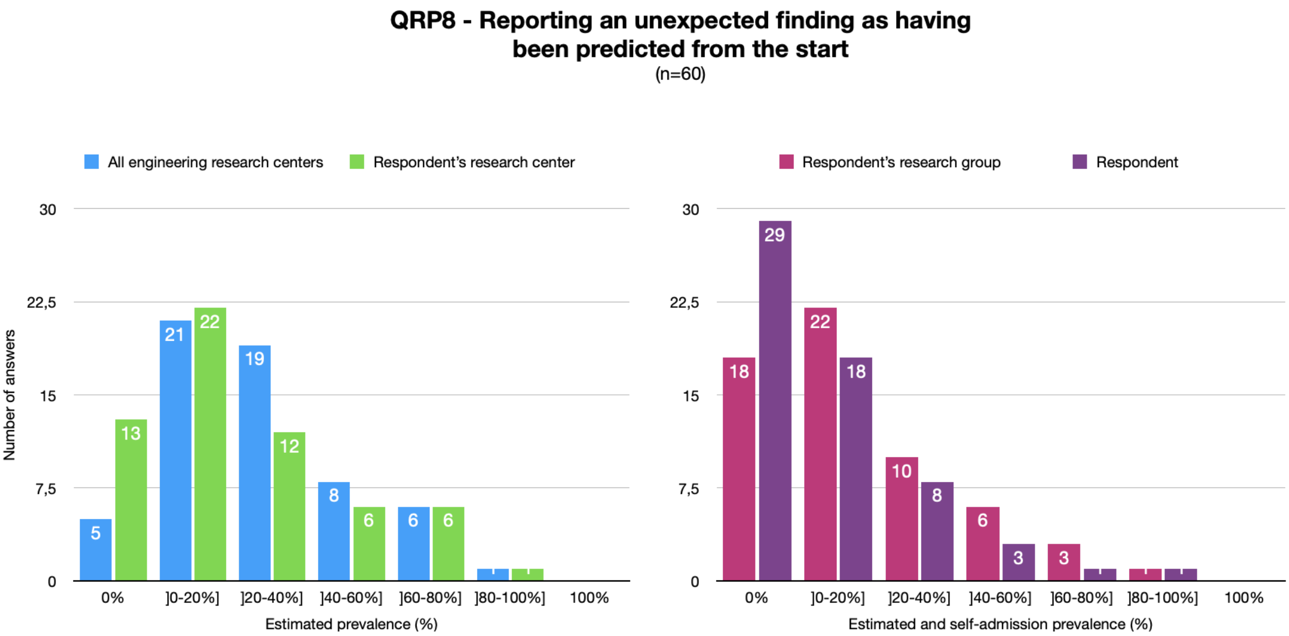


Fig. 10. Estimated and self-admission prevalence of QRP8

Table 8 . Mode and median classes for the estimated prevalence of QRP8 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0%-20%] | ]20%-40%] |
| Respondent's research center | ]0%-20%] | ]0%-20%] |
| Respondent's research group | ]0%-20%] | ]0%-20%] |
| Respondent | 0% | ]0%-20%] |

Others do not see justification: "I think that an unexpected result can have two causes: either it's due to poor contextualization and review of the literature on the subject; or it has to do with something that wasn't expected and there was no evidence that it could happen and, in the latter case, this "surprise" shouldn't be 'hidden,' i.e., it makes sense to report that it wasn't expected." Another one says: "it had never occurred to me – until I read this question in this questionnaire – that there could be a possibility of reporting an unexpected discovery as predicted from the start." Still, another opinion is that "A well-written and well-founded paper doesn't need this kind of fluff. If the discovery is unprecedented, I think the researcher should just try to explain it or leave it as 'future work'."

Concerning QRP9 - In a paper claiming that results are unaffected by demographic variables (e.g., gender), although one is unsure (or knows that they do), most respondents (75.0%) argue that they did not resort to this practice, leaving 25.0% admitting having engaged in QRP9 in at least one study (Fig. 11). As with other QRPs, self-admission in QRP9 has a higher prevalence than in John and colleagues (2012) (3.0%), Agnoli and colleagues (2017) (3.1%) and Latan and colleagues (2023) (20.34%).

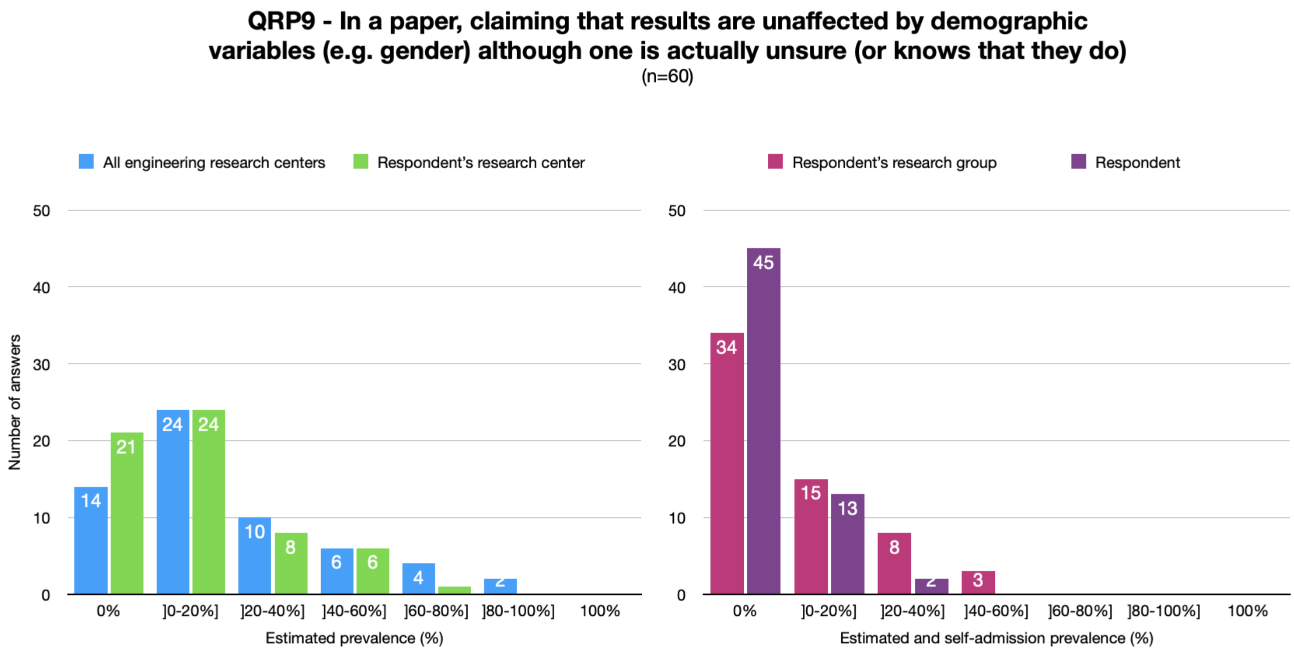


Fig. 11. Estimated and self-admission prevalence of QRP9

In addition, 56.7% of respondents also estimate that researchers in their research group do not resort to this practice. Only when asked about researchers from their and all research centres, do we find that 40.0% of respondents estimate the prevalence of this practice up to a percentage of over 0 to 20%. The mode class of the estimated prevalence for engaging in QRP9 is 0% in self-admission and in the respondent's research group and ]0-20%] for the remaining categories. The median is situated in the ]0%-20%] class for all engineering research centers and the respondent's research center, and the 0% class for the respondent and the respondent's research group (Table 9). The estimated prevalence for QRP9 by John and colleagues (2012) is 18.72%, by Agnoli and colleagues (2017) is 28.55%, and by Latan and colleagues (2023) is 36.72%.

Table 9 . Mode and median classes for the estimated prevalence of QRP9 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0%-20%] | ]0%-20%] |
| Respondent's research center | ]0%-20%] | ]0%-20%] |
| Respondent's research group | 0% | 0% |
| Respondent | 0% | 0% |

Some researchers (11.7%) state no circumstances justify using this practice. Others refer to the need to present results and the pressure to publish. One respondent says: "This question has to do with the literature review... this practice may occur because the researcher defends one of the perspectives, although he cannot say it is an unequivocal question. Alternatively, it may also be because, once again, the researcher considers that it is a dependency that the scientific community does not expect or does not meet the results obtained and, therefore, either manipulates the results or reports dubious assumptions."

Another respondent states, "There is no problem, as long as it is stated that it is the researcher's opinion (opinion supported by personal experience is valid, as long as it is said that it is so)." Still, another respondent claims that data must support this kind of assertion but admits the possibility of using a dubious discourse: "A more reserved but also argumentatively supported statement may be preferable, such as 'Demographic variable X is not expected to have had a measurable impact on the results, since Y.'"

Some answers seem to indicate that some respondents related this QRP to gender inequality or gender bias. For example, one respondent claims that Engineering research is indifferent to gender issues. Another respondent states that this practice may be justified "To make the conclusion more interesting or to avoid the controversy of gender inequality." Another respondent argues, "It is something extremely difficult to prove or subject to 'fads.'"

Finally, analysing QRP10 - Falsifying data, when asked about the prevalence of this practice, almost all (93.3%) respondents said they never resort to this practice, leaving 6.7% admitting to having engaged in it in at least one study (Fig. 12). As with other QRPs, self-admission in QRP10 has a higher prevalence than in John and colleagues (2012) (0.6%), Agnoli and colleagues (2017) (2.3%), but not Latan and colleagues (2023) which present a very high self-admission prevalence for QRP10 (44.70%).

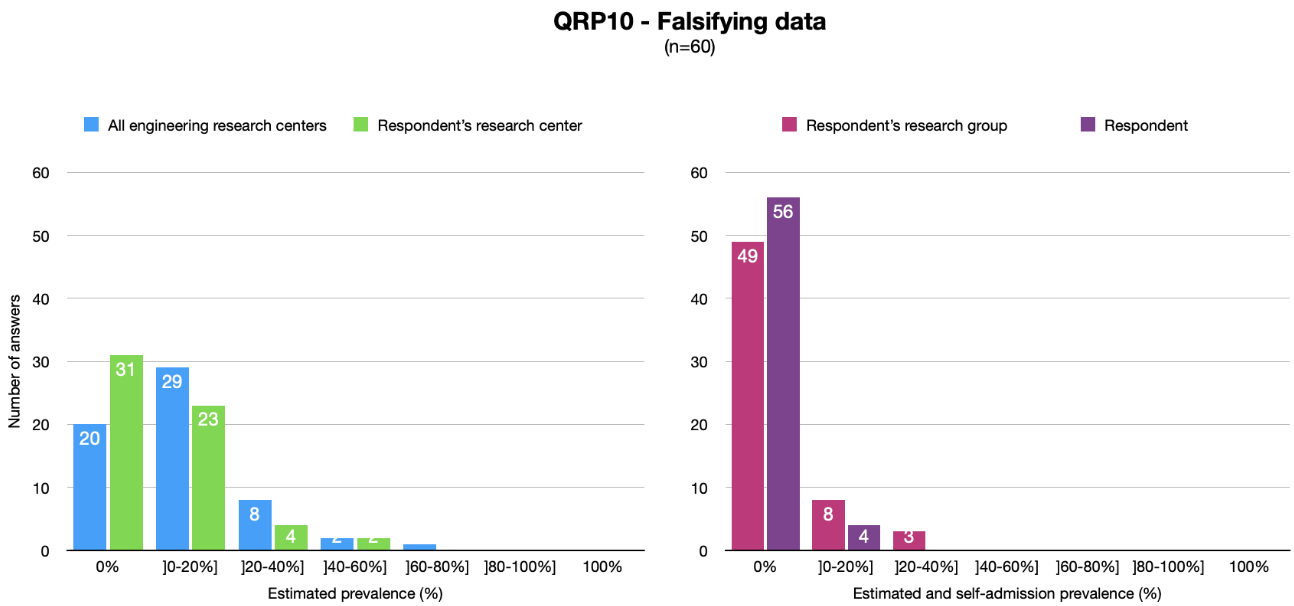


Fig. 12. Estimated and self-admission prevalences of QRP10

However, when asked about researchers from all research centres, we find that a large percentage (48.3%) estimate a prevalence of this practice of over 0 to 20%. The mode class of the estimated prevalence for engaging in QRP10 is 0% for all categories, except in all engineering research centers, which is ]0-20%] (Table 10). The same is true for the median class. The estimated prevalence for QRP10 by John and colleagues (2012) is 9.33%, by Agnoli and colleagues (2017) is 18.65%, and by Latan and colleagues (2023) is 51.31%.

Table 10. Mode and median classes for the estimated prevalence of QRP10 in all categories.

| Category | Mode class | Median class |
|---|---|---|
| All engineering research centers | ]0%-20%] | ]0%-20%] |
| Respondent's research center | 0% | 0% |
| Respondent's research group | 0% | 0% |
| Respondent | 0% | 0% |

Many respondents (31.7%) considered this QRP unacceptable: "Lack of professionalism, and nothing justifies this practice," "under no circumstances," or just "Inadmissible." A respondent claims this QRP happens "largely because [...] results are not in line with what would be expected."

Some refer to the lack of support, lack of funds, and pressure to publish: "To have results that justify funding" or "Zero [situations in which it is justifiable], but that's the pressure we are under because of the lack of support and funding." Another respondent says, "None [situations in which it is justifiable]. It just happens to get good results and influence the community."

Some respondents relate this practice to generating data for tests: "Depending on the situation, it doesn't involve falsifying, but rather generating data for testing. [This is] Another common practice in this area, as long as it is explained as such". Another respondent says, "The omission, transformation, and aggregation of data is a common practice that may or may not be considered falsification [...] In the case of extensive and detailed datasets, it is common to work with metadata, subsets, or processed data. In these scenarios, you can involuntarily incur a scenario of data falsification by omitting processes and operations. Alternatively, data may have been erroneously transcribed or calculated, which explains a publication with false data."

## 5. Final Remarks

Misconduct in science is not new. The scientific community itself has taken on the role of preventing misconduct, scrutinizing processes, and punishing irregular practices. The reasons for adhering to misconduct are identified in the literature, including pressure to publish, pressure to raise funds, perverse incentives, and tenure. Research institutions, scientific associations, funding agencies, and other organizations create codes of conduct and carry out training on this subject. The main breaches of conduct are considered the FFP. There is consensus about classifying these as misconduct, but there are some practices (QRPs) that, while permissible in some contexts or situations, are not in others. These practices are in the grey area between misconduct and responsible research conduct.

There are several identified QRPs. John and colleagues (2012) measured the estimated prevalence of ten QRPs in psychology. Their results caused surprise and concern, which led other researchers in psychology and other fields of knowledge to replicate their study or carry out similar studies with variations in methodological procedures. Other observational studies have also been conducted for different purposes, objects, and methods. The results also vary, but the vast majority of authors agree that the level of engagement in these practices is far from rare and is higher than that found in FFP. Engineering is a field where similar studies are rare, so we considered it pertinent to carry out an exploratory study that would shed some light on the subject and allow us to compare the results with other results from previous studies.

Therefore, this study aimed to obtain a snapshot of the estimated prevalence of the ten QRPs in engineering. The scope of the study was initially limited to researchers at Portuguese engineering research centers for convenience and the expected ease of obtaining responses. A questionnaire survey was administered in Portuguese, and researchers at Portuguese engineering research centers were asked to respond and disseminate the questionnaire to their colleagues. Of the 69 responses, 60 were considered valid.

*The results indicate that some questionable research practices, such as failing to report all relevant dependent measures that are relevant for a finding, collecting more data to render non-significant results significant, and selectively reporting studies related to a specific finding that "worked," have a higher estimated prevalence than practices like data falsification, which are reported with lower estimated prevalence. It is also interesting to note that, for many of the QRPs, the percentage of respondents who report never having observed or practiced them ("0%") tends to be higher for the respondents themselves than for their group, center, or all engineering research centers. This might indicate a lower perception of the prevalence of these practices at the individual level or a reluctance to admit their involvement or knowledge of these occurrences. It is important to note that this data represents reports from respondents and not an objective verification of the occurrence of these practices. However, they provide valuable insight into the perception and potential prevalence of various questionable research practices in engineering research.*

Most respondents justify the adherence to these practices with publication and time pressures, report findings consistent with their hypotheses, use methods that increase chances of publication, time and space constraints, journals, editors, or reviewers constraints. It is also apparent that some respondents have difficulty creating a border between what is ethical, dubious, or fraudulent and what is not.

Like any other scientific study, this one has limitations. Firstly, the study was carried out, by option, only in Portuguese engineering research centers. It would be interesting to open it up to other countries, and it would also be interesting to open it up to different areas in Portugal or Portuguese-speaking countries.

The answers to the open-ended question (what circumstances could justify this practice?) indicate that several respondents confused justification with explanation, i.e., they did not present conditions that they thought would make a QRP acceptable; instead, they tried to explain the causes of the practice. It will, therefore, be necessary to revise the questionnaire, clarify the wording of this question, and possibly include another question to determine the causes of adherence to each QRP. One respondent said several times that the meaning of the QRP was unclear to them. This can happen in the future with other respondents. To reduce the possibility of misinterpretation, adding information that briefly explains the meaning of each QRP with examples might make sense.

We also need to work on the lists of QRPs to study in engineering. The 10 QRPs we used in this study cross-cut across many fields of knowledge, but not all engineering disciplines. We can do sectoral studies or try to identify the QRPs that are most applicable across engineering. Either approach can contribute to a more accurate picture of engagement in QRPs in engineering.

The above paragraph in italics was almost all generated automatically using Notebook LM. “Notebook LM is an experimental AI tool developed by Google Labs, designed to assist in organizing and understanding information within documents.” This text in quotes was generated by Gemini, an Artificial Intelligence (AI) model developed and made available by Google. At a time when many of these tools are available to support research and other activities and are increasingly accurate in their analysis and reporting of results, it is worth questioning the limits of their use. What are the questionable research practices on using these tools, their limits on use, and how prevalent are they?

As stated above, this study was exploratory. It does not intend to provide final answers or to be generalizable. There are several reasons why it is not, starting with the sample size, the respondents' representativeness by field of expertise, age, and number of years doing research. Instead, it is an exploratory study that provides a first perspective, indicating that perhaps all is not well in engineering research. It calls for further studies, including qualitative ones, as we need to deeply understand the current situation and its potential causes and impacts.

As Banks, Rogelberg and colleagues argue (2016), the scientific literature is full of great examples of sound research practice. However, these authors also argue, and we second them, that the rates of involvement in QRPs “surpass what should be considered acceptable”. Therefore, measures need to be taken. Some measures could include no longer giving publication preference to positive results in journals, removing perverse incentives by changing performance evaluation procedures at research institutions, or when awarding research grants or project funding at funding institutions. Science is fundamental to the well-being of individuals and societies, so fostering sound scientific practices is essential.

## Acknowledgments

We thank Daniele Fanelli for introducing us to the studies on QRPs. We also thank the Editor-in-Chief, João Varajão, who generously reviewed a prior version of this article and invited us to publish it, as well as Gerarda Ribeiro, whom we consulted for statistical advice.

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2026, 14(1), e140101, DOI: 10.12821/ijispm140101

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**International Journal of Information Systems and Project Management (IJISPM)**
2026, 14(1), e140102, DOI: 10.12821/ijispm140102

RESEARCH ARTICLE

# Quality, security, and privacy assurance in software development: proactive integration or just workflow-slowing checkpoints?

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**Abstract**
In software development, the integration of assurance methodologies such as quality, security, and privacy practices is essential to producing high-quality, reliable, and compliant products. This paper investigates the adoption and effectiveness of these assurance practices within the daily operations of software development. Through an industry survey of 88 software development professionals in Finland, this study examines the order and consistency with which developers apply assurance practices during projects, and the challenges they face in performing these tasks. The results show that while developers recognize the importance of assurance, many organizations still treat it as a separate, secondary activity rather than a core part of the development lifecycle. Key findings show that quality practices are more consistently integrated into daily operations compared to security and privacy measures, which tend to be reactive. The paper highlights the tension between agile practices, which promote flexibility and continuous improvement, and the more rigid, process-heavy nature of assurance tasks. The study underscores the need for a shift in both industry practices and educational approaches to fully embed assurance into software development.

**Keywords**
quality; security and privacy; assurance practices; industry survey; software development practices; systemicity; compliance.

Received: 9 January 2025 | Accepted: 22 April 2025

International Journal of Information Systems and Project Management (IJISPM)
2026, 14(1), e140102, DOI: 10.12821/ijispm140102

## 1. Introduction

In any software development project, the importance of integrating assurance methodologies and best practices cannot be overemphasized. Software developers need to consider a variety of assurance methodologies, frameworks, and best practices that are necessary to ensure that the software development process is efficient, high quality, and secure. A basic understanding of quality, security, and privacy is part of the software engineering competency domain. These practices are not just formalities. Without them, even the most well-intentioned development efforts can fail, leaving vulnerabilities, inefficiencies, and compliance issues that can severely impact the success of a project.

Software developers must adopt a combination of proven frameworks, industry standards, and guidelines to deliver reliable software. These include practices such as Clean Code (Hutton, 2009), Agile (Agile Alliance, 2024), Software Development Lifecycle (Ruparelia, 2010), Dev(Sec)Ops (NIST, 2020a), and Continuous Integration/Continuous Development (Gallaba, 2019). These methodologies focus on iterative improvements, fast feedback, and continuous testing to ensure that the product is developed in a scalable and maintainable manner. Various quality and testing practices, such as Test-Driven Development (Beck, 2022), load and performance testing (Menascé, 2002; Neely et al., 2000), exploratory testing (Itkonen & Rautiainen, 2005), and penetration testing (Arkin et al., 2005) push the boundaries of quality assurance by not only identifying software defects, but also actively preventing security and privacy issues at the earliest possible stage. Security and privacy are critical in today's interconnected world, where breaches and leaks can cost organizations financially, legally, and reputationally. Adherence to OWASP (OWASP, 2024), the National Institute of Standards and Technology (NIST) Cybersecurity Framework (NIST, 2024b), and the International Organization for Standardization (ISO) 27001 (ISO27001, 2022) is not only good practice, and compliance with regulations such as the General Data Protection Regulation (GDPR) (GDPR, 2018) and the California Consumer Privacy ACT (CCPA) (CCPA, 2024) is not just a legal necessity. These are not optional tasks; they are critical to building software that works reliably. These practices are necessary to build trust with users who demand high-quality, secure, and privacy-enhancing solutions.

Implementing assurance practices is more than just ticking boxes. The adoption of assurance practices is essential to ensure robust and reliable results. Yet assurance activities can often feel like a "Band-Aid" applied to software development practices, perceived as slowing and complicating the workflow by addressing seemingly marginal issues. This paper emphasizes that *security* and *privacy* should not be subsumed under the broad term "*quality*" in software development, because of their distinct goals, characteristics, and critical importance. Although related, each of these areas addresses fundamentally different concerns and requires specialized methodologies, tools, expertise, and unique frameworks and standards. While security and privacy contribute to the overall quality of software, each has its own importance and requires separate evaluation processes. Framing them as quality, security, and privacy assurance emphasizes their equal importance while supporting collaborative approaches to align these areas with broader goals.

This paper aims to investigate how software developers engage with assurance practices throughout the software development process. We aim to understand the order in which developers follow and adhere to various practices during a project, and how well assurance practices are performed on a day-to-day basis. This paper addresses the following research questions:

*RQ1: In what order do software developers follow and adhere to assurance practices during a project?*

*RQ2: How systematically do software developers select assurance practices and how are these practices regulated?*

*RQ3: How well do software developers implement or use the assurance practices in their organization?*

To address these research questions, we surveyed 88 software development professionals in Finland to explore their quality and security assurance practices and their perceptions of software development processes. By answering these questions, the research aims to gain an understanding of the adoption, application, and performance of quality, security, and privacy assurance practices in the industry.

Clearly, the single term "quality" in software development does not fully capture the depth of developers' quality practices. In this paper, additional terms related to quality must be included to provide a broader understanding. *Quality* in software development encompasses various activities and aspects that ensure that the software meets user needs, business requirements, and technical standards. These include, such as functional quality, non-functional quality, process quality, operational quality, and considerations including compliance, satisfaction, and risk and change management. *Testing* plays a critical role in ensuring both functional and non-functional quality, while maintaining a sustainable and reliable software product throughout its lifecycle. Software quality must also address *technical debt* (Kruchten et al., 2012; Li et al., 2015; Tom et al., 2013). Technical debt has a direct impact on the internal quality, long-term maintainability, scalability, and performance of software, because it undermines the effectiveness of testing, increases the likelihood of defects, complicates test automation and regression testing, and degrades the overall quality of the software.

The paper is organized as follows: Section 2 provides an overview of previous studies and basic concepts in assurance practices. Section 3 outlines the research methods and details the research conducted. Section 4 presents the results, starting with the order of the following practices to be followed, then examining systemicity and compliance in the selection of assurance practices, followed by day-to-day assurance practices. Section 5 presents a discussion and Section 6 is the conclusion of the study.

## 2. Literature review

Software failures have repeatedly led to serious consequences, from financial losses and data breaches to loss of life, as seen in cases, such as the Y2K bug, Toyota's unintended acceleration, Ariane 5, and Therac-25 (Raygun.com, 2022;Medium.com, 2020;Wired.com, 2022) failures. These disasters highlight how failures in assurance and human error can have catastrophic consequences. Today, the risk of poor-quality, insecure software slipping through is higher than ever, and security and privacy breaches resulting from exploited vulnerabilities are common. For these reasons, knowledge and skills in quality, security, and privacy assurance are in high demand in software development. However, it is important to recognize that even these assurance practices do not guarantee a 100% error-free result.

Quality, security, and privacy form a triangle that covers the essential assurance aspects of information systems and processes. This triangular concept reflects the interrelationships and potential conflicts between these aspects, particularly in software development. By looking at them together, it is possible to ensure that a system or process is holistically reliable, secure, and privacy-aware. Looking at these practices together can help identify how changes or actions in one area affect the others. The following assurance definitions are defined and constructed using descriptions from ISO25002:2024 (ISO25002, 2024), IEEE 730-2014 (IEEE, 2014), CMMI (CMMI Institute, 2018), ISO27001 (ISO27001, 2022), NIST (NIST, 2024a), OWASP (OWASP, 2024), ISO15408 (ISO15408, 2022), GDPR (BBC News, 2021; GDPR, 2018), ISO29100 (ISO29100, 2024), CCPA (CCPA, 2024), and Privacy by Design - The 7 Foundational Principles (Cavoukian, 2009):

*Quality assurance* in software development is a systematic process designed to ensure that a product or service meets specific requirements. It involves systematic measurement, comparison to standards, process development and monitoring, and feedback loops that promote error prevention. Key aspects include documenting and enforcing defined processes during development, continuously monitoring processes, training team members, conducting audits and reviews to verify compliance with standards, and implementing feedback mechanisms to improve processes. (CMMI Institute, 2018; IEEE, 2014; ISO25002, 2024)

*Security assurance* in software development ensures that software is free of vulnerabilities throughout its lifecycle and performs as intended. The process involves assessing risks, defining security requirements, employing secure design and coding practices, and conducting thorough security testing. It also includes managing software configurations and changes, establishing incident response protocols, and adhering to relevant security standards and obtaining necessary certifications to effectively mitigate potential security threats and ensure compliance. (ISO15408, 2022; ISO27001, 2022; NIST, 2020c, 2020b; OWASP, 2024)

*Privacy assurance* in software development ensures that software manages data in compliance with privacy standards and regulations, and respects user privacy throughout the data lifecycle. This includes building privacy into the earliest design phases, minimizing data collection to what is strictly necessary, and implementing strong access controls. It also includes encrypting and anonymizing data to protect user identities, complying with regulations such as GDPR and CCPA, and maintaining transparency and accountability in data use. (GDPR, 2018; ISO29100, 2024; CCPA, 2024; Cavoukian, 2009)

Webster and Watson (2002) emphasize that a literature review should summarize, synthesize, and critically analyze research to identify gaps, provide a conceptual framework, and suggest future directions. They recommend defining a clear scope, using systematic methods to evaluate sources, and organizing findings with an audience in mind, supported by visual tools such as tables and graphs. Because assurance practices are well known and have been extensively researched, this review focuses on the most recent research on assurance practices and differs from Webster and Watson's (2002) approach by not limiting the review to the timeframe of the industry survey. The identified practices frame the findings and structure the analysis in Section 4. The review is based on IEEE Xplore, a database that specializes in technical and engineering fields directly relevant to software engineering and computer science. Using a single database narrows the scope, simplifies the process, and avoids duplication while leveraging IEEE's role in developing and publishing standards. However, this approach excludes interdisciplinary perspectives and provides a narrower view of research. While IEEE includes strong work on quality and security, it was recognized that its coverage of privacy is less focused, although privacy-related research is expected to grow in the future.

We conducted a focused review of recent research (years 2020-2024) on quality, security, and privacy assurance in software development using IEEE Xplore. The primary search used the terms: ("document title": quality assurance) OR ("document title": security assurance) OR ("abstract": privacy assurance) AND ("document title": software) AND ("publication title": development), filtered by conferences, journals, and standards, yielding 210 results. Broader search terms such as "in software development" returned additional results: Privacy Assurance (56), Security Assurance (223), Quality Assurance* (504), Quality and Security Assurance* (124), Quality and Privacy Assurance* (17), and Security and Privacy Assurance* (47). After excluding articles that were not open access, not in English, or focused only on educational programs, 24 articles remained from the main search and 9 from the broader searches. These 33 articles were reviewed in full, and the results are summarized in Table 1.

The literature review (Table 1) shows that 80 % of the articles related to software assurance focus on quality assurance, and about 50 % of the articles deal with security assurance, so the importance of security assurance has already become relatively significant in the field of assurance. Of these, about 18 % deal only with security assurance, not combined with the quality assurance viewpoint. Surprisingly, only one article dealt with the privacy assurance aspect. This suggests that privacy assurance is not yet as strongly emphasized in assurance practices as quality or security. The importance of privacy assurance is expected to grow, as GDPR has only been in effect for six years and organizations are still integrating privacy assurance into their software development practices.

Based on the literature analysis, the research to date has largely addressed the aspects summarized in the definitions of quality, security and privacy assurance above. A very popular perspective (about 55 % of the papers) is to look at assurance in software development from the perspective of Agile/Waterfall methodology, the software development life cycle, and DevOps/DevSecOps. About 50 % of the articles dealt with testing (including security testing). The aspects covered in the articles varied. Several articles highlighted the importance of testing as part of assurance practices (Wong et al., 2022), how different testing techniques and practices are part of the development process, influence the outcome, and serve as quality control (Deshpande et al., 2023; Galindo-Francia & Auccahuasi, 2024; Jonathan et al., 2020). Articles also provide perspectives and differences between traditional waterfall and agile testing (Sinha & Das, 2021). Articles present ideas on how to reduce the testing effort by increasing code review effort (Nakahara et al., 2021) or how to provide an overview of good practices in the area of testing of software solutions (Holjevac & Jakopec, 2022). Other topics include the impact of international standards on software quality and software testing (Zhao et al., 2021), and the use of automation (Gonen & Sawant, 2020). For security testing, perspectives emerge where cybersecurity should be built as an integral part of the quality assurance testing process (Haider & Bhatti, 2022), security testing methods (Khan et al., 2022), and testing practices such as penetration testing (Siang & Selvarajah, 2022) or practices where manual security testing should be performed (Arnold & Qu, 2020). The use of different tools, technologies or automation was also mentioned very often.

The third very popular approach in articles (about 36 %) is to offer proprietary solutions, frameworks, models, metrics, or approaches for developing or ensuring assurance. The following frameworks or models were proposed as solutions: the SQA-PAK model (Deshpande et al., 2023), a simulation model of software quality assurance (Nakahara et al., 2021), an adoptable guideline for mitigating the problems and implementing a quality framework (Shikta et al., 2021), the MAC methodology (Galindo-Francia & Auccahuasi, 2024), Scrumlity framework (Tona et al., 2021), proposals with standards (Zhao et al., 2021), and factors to balance control and autonomy to reduce security challenges in large-scale agile development. It was also suggested that the software quality assurance process should include additional steps such as code review and penetration testing for cybersecurity implementations (Haider & Bhatti, 2022). A conceptual framework for identifying the correctness, consistency, and completeness of security requirements (Janisar et al., 2023) and metrics for measuring the performance of regulatory attributes (Wagner & Ford, 2020) have been proposed.

The articles also cover various standards, models, frameworks, and metrics as part of software development or their impact as part of software development. For example, the ISO 9000, 25000, and 27000 series standards, CMMI, Six Sigma, Total Quality Management, EFQM, and Security Assurance Model were discussed (Deshpande et al., 2023; Khan et al., 2022; Mishra, 2023; Wong et al., 2022). Requirements and validation were also discussed in several articles (Cohen et al., 2021; Deshpande et al., 2023; Filipovikj et al., 2020; Hynninen & Jantunen, 2022; Nägele et al., 2023; Shikta et al., 2021). Security requirements have also been emphasized (Haider & Bhatti, 2022; Janisar et al., 2023; Khan et al., 2022; Mishra & Mustafa, 2020; Wagner & Ford, 2020).

Some of the articles discuss and highlight typical quality assurance practices, their success, or ways to improve practices. For example: (secure) coding and coding reviews (Haider & Bhatti, 2022; Hynninen & Jantunen, 2022; Jharko, 2021; Khan et al., 2022; Nakahara et al., 2021; Ramirez et al., 2020; Wong et al., 2022); design, analysis, and documentation of assurance and quality practices and plans (Deshpande et al., 2023; Janisar et al., 2023; Mishra & Mustafa, 2020; Shikta et al., 2021; Wong et al., 2022). In addition, the articles discussed process adoption and continuous process improvement, and the importance of roles and responsibilities as part of the process or software development (Deshpande et al., 2023; Galindo-Francia & Auccahuasi, 2024; Khan et al., 2022; Nägele et al., 2023; Shikta et al., 2021; Wong et al., 2022). Different metrics, key performance indicators, and service level agreements are discussed (Deshpande et al., 2023; Filipovikj et al., 2020; Galindo-Francia & Auccahuasi, 2024; Wagner & Ford, 2020; Wikantyasa et al., 2023; Wong et al., 2022), and corrective/preventive actions are also emerging in the context of validation and verification (Atoum et al., 2021; Deshpande et al., 2023; Jharko, 2021a; Khan et al., 2022; Nakahara et al., 2021; Shikta et al., 2021; Wong et al., 2022). The articles also covered some tools for assurance monitoring and management during development projects and management-related topics such as quality management system and risk management (Haider & Bhatti, 2022; Janisar et al., 2023; Jharko, 2021a; Khan et al., 2022; Khurana & Wassay, 2023; Mishra, 2023; Nägele et al., 2023; Niu et al., 2024; Wong et al., 2022). The importance of architecture and design as part of assurance is also noted in articles (Cohen et al., 2021; Janisar et al., 2023; Jonathan et al., 2020; Khan et al., 2022; Kharchenko et al., 2021; Wikantyasa et al., 2023). Only a few articles discuss the importance of training or maintaining and developing competencies (Deshpande et al., 2023; Hynninen & Jantunen, 2022; Khurana & Wassay, 2023; Nägele et al., 2023; Niu et al., 2024). Surprisingly, there were only two papers that addressed the entire supply chain and the consideration of software development vendors as part of the assurance practices (Filipovikj et al., 2020; Khan et al., 2022).

Table 1. Quality, security and privacy assurance literature review (years 2020-2024)

| Articles | (Cyber) Security | Quality | Privacy | Standards, Models, Frameworks (ISO, CMMI, OWASP etc.), certification | (Secure) Coding and Code review, Software/code errors | Testing and testing methods | Security testing, penetration testing | Security risks/Risk mgmt | Security / Privacy requirements | Requirements and requirements validation | Tools and Techniques, automation | Quality Management system, Quality Process and Framework (EFQM) | Own Proposed solution/process/framework/metrics | Assurance/quality planning, Analysis, specifications, plans, documentation, checkpoints | Process implementation, Continuous development, Process improvements | Metrics, KPIs, SLA | Roles & Responsibilities | Verification & Validation | CAPA | Knowledge, training and education | Architecture and design | Agile/Waterfall methodology, software development lifecycle, DevOps | Vendor/Supply chain/outsourcing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arnold & Qu (2020) | x | x | | | | x | x | | | | | | | | | | | | | | | x | |
| Atoum et al. (2021) | | x | | | | | | | | x | x | | | | | | | x | x | | | | |
| Cohen et al. (2021) | x | | | | | | | | x | x | | | | | | | | | | | x | x | |
| Deshpande et al. (2023) | | x | | x | | x | | | | x | | | x | x | x | x | | | x | x | | | |
| Filipovikj et al. (2020) | x | | | | | | | | x | x | | | | | | x | | | | | | | x |
| Galindo-Francia & Auccahuasi (2024) | | x | | x | | x | | | | | x | | x | | x | x | | | | | | | |
| Gonen & Sawant (2020) | | x | | | | x | | | | | x | | | | | | | | | | | x | |
| Haider & Bhatti (2022) | x | x | | x | x | x | x | | x | x | x | x | x | | | | | | | | | | |
| Holjevac & Jakopec (2022) | | x | | | | x | | | | | | | | | | | | | | | | | |
| Hynninen & Jantunen (2022) | | x | | | x | | x | | | x | x | | | | | | | | | x | | | |
| Janisar et al. (2023) | x | x | | | | | | x | x | | | | x | x | | | | | | | x | | |
| Jharko (2021) | | x | | | x | | | | | | | x | x | | | | | | x | | | x | |
| Jonathan et al. (2020) | | x | | | | x | | | | | x | | | | | | | | | | x | | |
| Khan et al. (2022) | x | x | | x | x | x | | x | x | | | | | | x | | | x | | | x | x | x |
| Kharchenko et al. (2021) | | x | | | | | | | | | | | | | | | | | | | x | x | |
| Khurana & Wassay (2023) | x | | | | | | | x | | | | | | | | | | | | x | | x | |
| Lochan (2021) | | x | | | | | | | | | | | | | | | | | | | | x | |
| Lotz (2020) | x | | | x | | | | | | | | | | | | | | | | | | x | |
| Mishra & Mustafa (2020) | x | | | | | | | | x | | | | | x | | | | | | | | | |
| Mishra (2023) | | x | | x | | | | | | | | x | | | | | | | | | | | |
| Nakahara et al. (2021) | | x | | | x | x | | | | | | | x | | | | | x | | | | x | |
| Niu et al. (2024) | x | x | | | | | | x | | | | | | | | | | | | x | | x | |
| Nägele et al (2023) | x | x | | | | | | x | | x | | | x | | | | x | | | x | | x | |
| Ramirez et al. (2020) | x | | | x | x | | x | | | | | | | | | | | | | | | x | |
| Salahat et al. (2023) | | x | | | | x | | | | | | | | | | | | | | | | | |
| Shikta et al. (2021) | x | x | | | | x | | | | x | x | | x | x | x | | x | | x | | | | |
| Siang & Selvarajah (2022) | x | x | | | | | x | | | | | | | | | | | | | | | | |
| Sinha & Das (2021) | | x | | | | x | | | | | | | | | | | | | | | | x | |
| Tona et al. (2021) | | x | | | | | | | | | x | | x | | | | x | | | | | x | |
| Wagner & Ford (2020) | x | x | x | | | | | | x | | | | x | | | x | | | | | | x | |
| Wikantyasa et al. (2023) | x | x | | | | | | | | | | | x | | | x | | | | | x | x | |
| Wong et al. (2022) | | x | | x | x | x | | | | | x | x | | x | x | x | x | x | x | | | x | |
| Zhao et al. (2021) | | x | | x | | x | | | | | | | x | | | | | | | | | | |

During the literature search, it became clear that IEEE does not yet contain many articles on privacy. This may be influenced by the technical focus of IEEE, and privacy-related studies are more likely to be found in other publishers. For example, the International Journal of Systems and Project Management has published privacy-related studies in recent years that focus on how the GDPR has affected consumers' knowledge, attitudes, and practices regarding their enhanced rights (Presthus & Sørum, 2024), the extent to which consumers are concerned about information privacy issues (Presthus & Sørum, 2019), and examining the violations and sanctions that have occurred following the implementation of the GDPR (Presthus & Sønslien, 2021). However, these articles do not focus on privacy aspects of software development and are therefore not fully within the scope of this literature review.

Previous research shows that quality practices are widely studied, and the topics covered are consistent with quality assurance definitions. The role and impact of security assurance is growing, requiring software developers to increasingly consider security assurance practices and requirements in their development work. Privacy assurance and related practices are not yet reflected in the articles, but their contribution is expected to be reflected in future assurance practices such as security assurance.

## 3. Research methods and survey implementation

This study uses a survey-based research methodology to gather insights from IT professionals on quality, security, and privacy assurance practices. The survey results are analyzed based on the most common assurance practices and focus areas as identified in the literature review. A key aspect is to look at the time taken to select assurance practices, i.e. how systematically and compliantly practices are selected and followed. The first step is to look at what typical quality, security, and privacy assurance practices are in place: plan, strategy, named process owner, writing requirements, defining targets, prioritizing requirements, defining acceptance criteria, and issue reporting. It then looks at the level/success of the assurance practices in use: documented processes, Corrective Action Preventive Action (CAPA), defined and documented roles and responsibilities, quality acceptance criteria, Key Performance Indicators (KPI), common rules, list of unsolved risks/defects, and a separate team for solving customer defects, and how well the companies implement the assurance practices in their day-to-day operations: software development practices, quality assurance, testing practices, security assurance, privacy assurance, technical debt management, risk management and reporting, clear Definition of Done (DoD), and use of standards and best practices. The decision to examine especially these areas is based on their recurring importance in the assurance literature as essential elements in maintaining software quality, security, and privacy assurance. In particular, the use of a separate team to address production issues presents a unique conflict: while a dedicated team can more directly address customer-side issues, this structure can also create communication gaps between the development and maintenance teams, potentially hindering awareness of production challenges.

The industry survey targeted Finnish software engineers and developers, using both an open online link (promoted by the University of Turku Alumni, FISMA and Sytyke ry) and direct email invitations to addresses publicly available on the Finnish Software Entrepreneurs Association website, following ethical and privacy guidelines by contacting only those companies with publicly listed email addresses or formats. The survey was conducted from October 2019 to February 2020, with reminders sent in November and December, and received 88 valid responses, about 71 % from the public link. Respondents were highly experienced, with 46% having more than 16 years of IT experience (3 % <1 year, 22 % 1-5 years, 16 % 6-10 years, 13 % 11-15 years, 46 % >16 years), and held roles in development, design, architecture, testing, and management. Respondents represented a range of company sizes, with 44 % from large companies (10 % <10 employees, 22 % 10-50 employees, 13 % 51-100 employees, 9 % 101-250 employees, and 44 % >250 employees). Most companies served the private sector (69 %) and provided complete software systems, consulting services, and SaaS products. The survey successfully reached experienced professionals in various roles, probably facilitated by FiSMA and Sytyke Ry's promotion of the survey, reflecting the Finnish software industry landscape. (Majanoja & Hakkala, 2023; Majanoja et al., 2023).

## 4. Results and analysis

This section presents the findings of the study, organized around the key research questions. The findings are divided into three sections. First, in Section 4.1, we examine the following order of practices, while Section 4.2 provides an overview of systemicity and compliance in selecting and following assurance practices. Next, we focus on day-to-day assurance practices, as Section 4.3 examines the implemented assurance practices (focus practices selected based on the literature review) and provides post-delivery findings focused on the assurance perspective. Taken together, these findings provide an overview of the role of assurance practices in day-to-day software development operations.

### *4.1 The order of adherence to practices*

The order of adherence to practices is as follows: first is software development practices, and second is quality. Third is security, and fourth is privacy practices. The fifth followed practice is testing, which is partly combined with quality and software development practices. The least followed practice is technical debt.

When analyzing the results by company size (Fig. 1), small companies view quality and security as the most critical assurance practices.

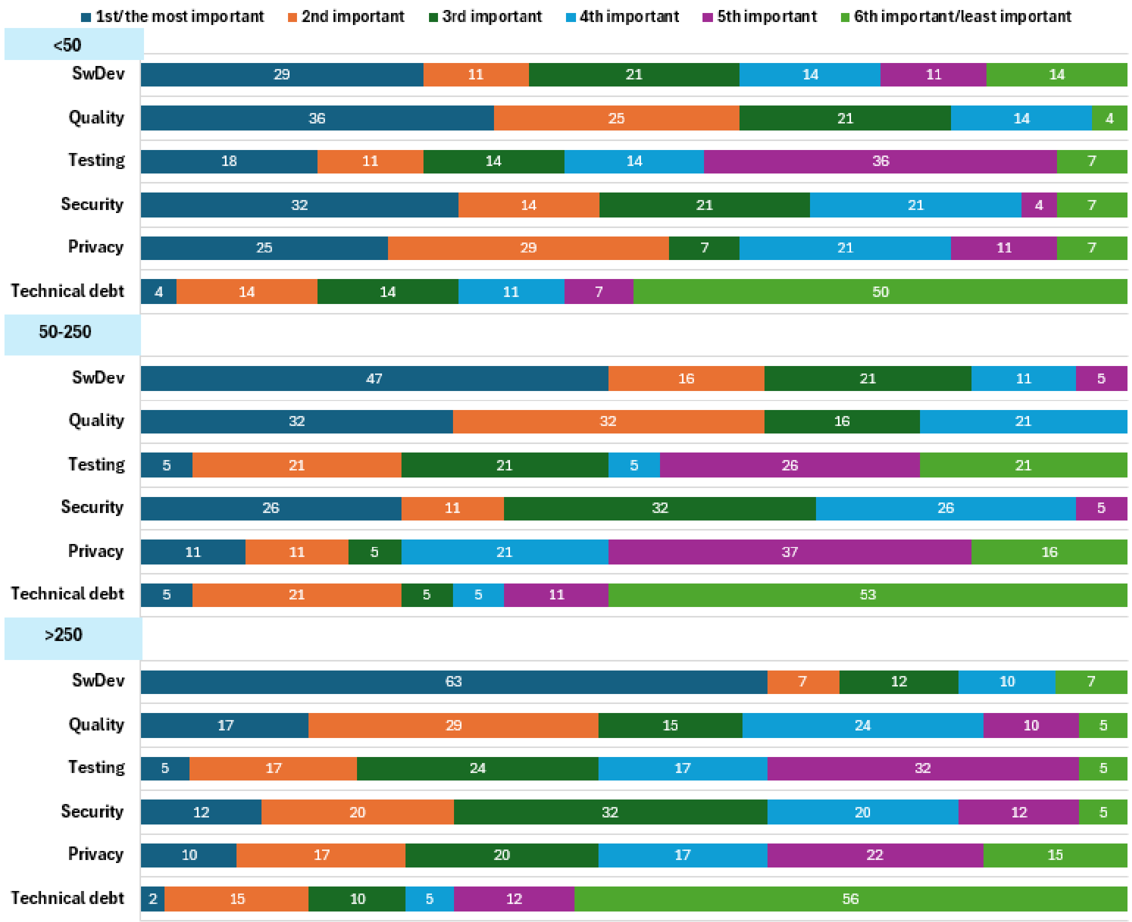


Fig. 1. Order of practice adoption in daily operations by company size (%)

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Software development (SwDev) is a high priority, but slightly behind quality and security. Testing and privacy show more variability, with testing often considered a lower priority than the others. Technical debt is consistently ranked as the least important practice. For medium-sized companies, SwDev and quality are the most important practices to follow. This suggests that ensuring the development process and maintaining quality are critical areas of focus for developers. Security also ranks high, with a significant number of developers ranking it as their first or third most important priority. Testing and privacy are more likely to be seen as lower priorities. This may indicate that testing practices are seen as complementary to software development and quality practices. Technical debt is consistently ranked as the lowest priority. This suggests that while technical debt management is recognized, it is not seen as urgent compared to other assurance practices.

In large companies (Fig. 1), SwDev practices are by far the most important. Quality is usually ranked second, indicating its importance, but less so compared to software development. Security and testing show a strong presence in 2nd or 3rd place and are generally considered medium priority practices. Privacy is typically ranked lower, with the majority placing it in 3rd, 4th or 5th place, indicating that while important, it is often deprioritized compared to security or testing. Technical debt is overwhelmingly ranked last by the majority, indicating that it is generally considered to be the least important practice in this context.

*4.2 The level of systemicity of the practices and the compliance with the regulations*

Analyzing the results (Table 2), about 40 % of small companies (<50 employees) use the same practices for all projects or sometimes make some changes, especially in software development (60 %) and quality (70 %), while testing practices are often defined on a project or ad hoc basis (47 %). Many small companies take an ad hoc approach to managing technical debt (32 %) and rely on ad hoc or project-specific approaches for data privacy (34 %) and security (43 %).

Medium-sized companies (51-250 employees) tend to use the same set of practices or make occasional adjustments, especially for security (69 %) and privacy (63 %). Software development practices are fairly consistent across 53 % of projects, and 53 % of projects follow a standard testing approach, although 32 % still use an ad hoc testing approach. Technical debt management is largely ad hoc (53 %), indicating variability or a lack of standardized processes.

In large companies (>250 employees), 60-70 % rely on predefined practices with occasional adjustments. Testing and quality practices are more adaptable, with 39 % and 24 %, respectively, sometimes changing. Security practices are either standard (39 %) or ad hoc (27 %), and while 32 % manage technical debt ad hoc, 58 % use a standard approach with some customization.

Based on Table 2, small companies rely heavily on project-level accountability, particularly for managing technical debt (64 %), software development (54 %), quality (54 %), and testing (54 %), suggesting a case-by-case approach to compliance. Medium-sized companies also emphasize compliance at the project level, particularly in testing (63 %), software development (42 %), and security (42 %). At large companies, project teams are most often responsible for compliance in areas such as technical debt (61 %), testing (61 %), and software development (51 %), reflecting an autonomy-oriented approach.

Privacy and security are more heavily regulated across all company sizes, with large companies more likely to adhere to strict processes, particularly in the area of quality (41 %). This structured approach is less evident in smaller companies, where formal compliance processes are less common, likely due to resource constraints and the need for agility. However, project-based compliance remains the dominant model across all company sizes.

Table 2. Systematic implementation of practices and compliance with regulations (%)

| Systemic approach in selecting methods and practices | | | | | Project compliance with regulations and policies | | | |
|---|---|---|---|---|---|---|---|---|
| Practice | Always same | Some-times changing | Systemati-cally defined on a per-project basis | Adhoc approach and adapting | Not regulated or described | Project's own responsi-bility | Broadly performed through regulations/ processes | Strictly in accordance with regulations/ processes |
| Small-size companies: <50 | | | | | | | | |
| SwDev | 36 | 25 | 11 | 29 | 29 | 54 | 11 | 7 |
| Quality | 32 | 36 | 11 | 21 | 25 | 54 | 14 | 7 |
| Testing | 36 | 18 | 29 | 18 | 18 | 54 | 21 | 7 |
| Security | 29 | 29 | 29 | 14 | 29 | 36 | 18 | 18 |
| Privacy | 36 | 21 | 32 | 11 | 25 | 29 | 25 | 21 |
| Technical debt | 32 | 21 | 14 | 32 | 32 | 64 | 4 | 0 |
| Medium-size companies: 51–250 | | | | | | | | |
| SwDev | 21 | 32 | 21 | 26 | 5 | 42 | 32 | 21 |
| Quality | 16 | 47 | 21 | 16 | 0 | 47 | 26 | 26 |
| Testing | 21 | 32 | 16 | 32 | 0 | 63 | 16 | 21 |
| Security | 32 | 37 | 16 | 16 | 16 | 42 | 16 | 26 |
| Privacy | 42 | 21 | 11 | 26 | 21 | 42 | 11 | 26 |
| Technical debt | 11 | 21 | 16 | 53 | 42 | 42 | 5 | 11 |
| Large-size companies: >250 | | | | | | | | |
| SwDev | 27 | 39 | 10 | 24 | 7 | 51 | 29 | 12 |
| Quality | 37 | 24 | 20 | 20 | 2 | 46 | 41 | 10 |
| Testing | 27 | 39 | 17 | 17 | 5 | 61 | 27 | 7 |
| Security | 39 | 24 | 10 | 27 | 10 | 39 | 34 | 17 |
| Privacy | 41 | 24 | 17 | 17 | 10 | 32 | 32 | 27 |
| Technical debt | 34 | 24 | 10 | 32 | 24 | 61 | 12 | 2 |

The analysis shows that company size has a significant impact on the use of the same standard set of practices versus ad hoc methods, especially in security practices. Larger organizations tend to be more process-driven, with established work practices that allow for some flexibility. In contrast, smaller companies also rely on ad hoc approaches, likely due to limited resources and the need to remain responsive in a changing environment. Regulatory compliance is typically the responsibility of the project, regardless of the size of the organization. These findings suggest that projects do not spend much time defining the set of practices they use or how they approach compliance on a day-to-day basis. Roughly speaking, they simply follow the same predefined set of practices regardless of the project or customer.

### *4.3 Success in implementing and performing assurance practices in daily operations*

*Implemented assurance practices.* The results in Fig. 2 show significant differences in the use of assurance practices (Not Used, Quality, Security, and Privacy). Across all company sizes, there is a relatively high rate of "Not Used" in areas such as defining KPIs and acceptance criteria, particularly among large companies, where 68 % do not use KPIs and 56 % do not use acceptance criteria. This indicates a widespread lack of consistent performance metrics or benchmarks.

In terms of quality practices implemented (Fig. 2), companies tend to prioritize quality practices over security and privacy, with more consistency in the use of defined acceptance criteria and planning, especially in small and medium-sized companies. However, security practices show greater variability and reliance on ad hoc methods. In small companies, 64

% manage security without formal prioritization of requirements or definition of KPIs, reflecting a less structured approach. Privacy practices are similarly inconsistent, with a significant proportion of companies using ad hoc or project-based methods, although large companies use slightly more formal processes for privacy than for security. It appears that while quality assurance practices are somewhat more formalized, security and privacy tend to be managed more inconsistently, particularly in smaller organizations, indicating potential vulnerability in these critical areas.

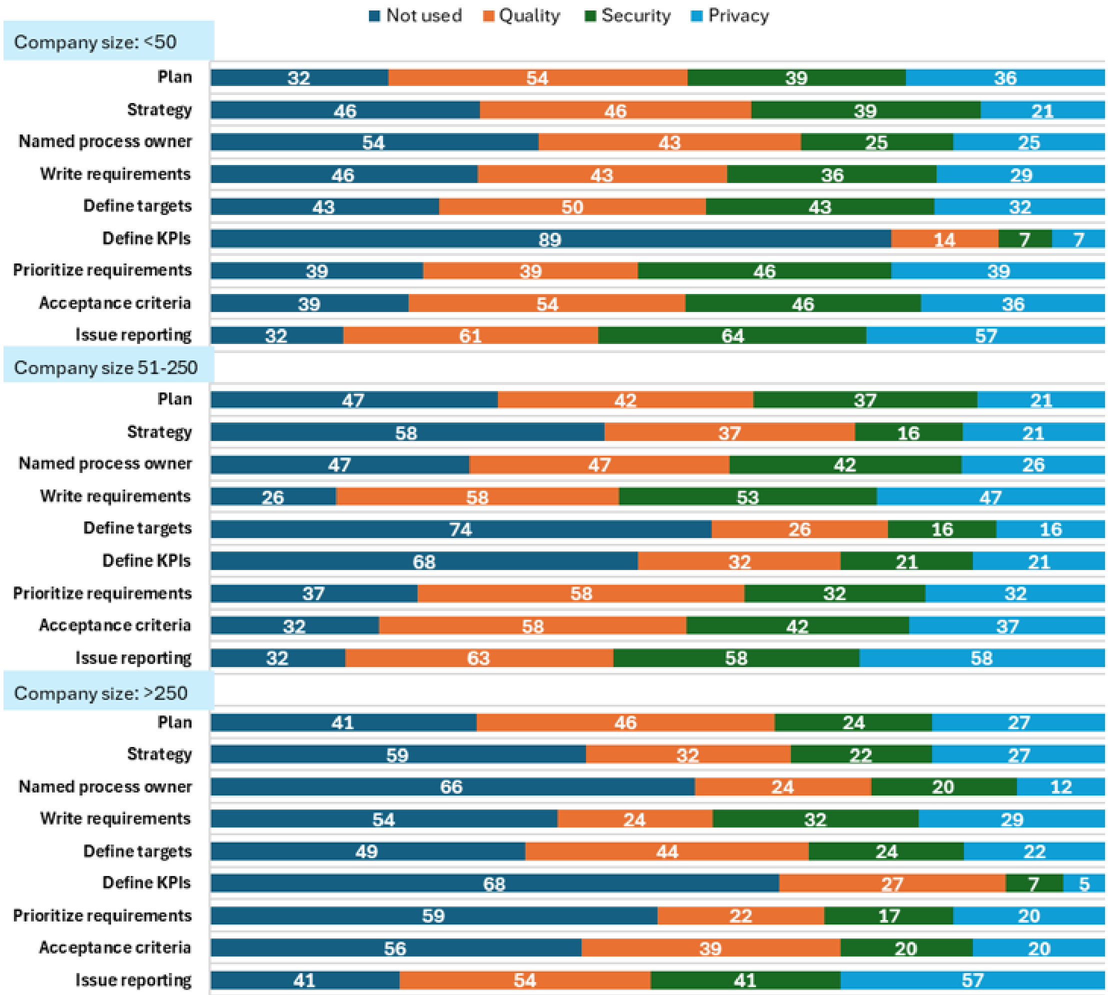


Fig. 2. Implemented quality, security and privacy assurance practices per company size (%) to daily operation

*Success of assurance practices.* In Table 3 and Fig. 3, we have selected common assurance practices and analyzed how well they are implemented in daily operations. The analysis (Table 3) shows that CAPA practices in particular are underrepresented among assurance practices across all company sizes. This is somewhat surprising, given that the purpose of CAPA is to gather and analyze information, identify and investigate product and quality issues, and implement effective corrective and preventive actions to prevent recurrence. In addition, the central focus of CAPA is to verify and validate the actions taken, communicate the CAPA action activities to responsible parties, provide relevant information for management review, and document these activities to prevent their recurrence and prevent or minimize failures (Majanoja et al., 2017).

The other underrepresented practice is defining and reporting KPIs (Table 3). This is particularly evident in small companies (57 % do not use), but larger companies also report challenges in defining and measuring KPIs. The use of dedicated team to solve production problems is intentionally ambiguous. Smaller companies do not use it, which is understandable given resource constraints, but at the same time it is good that developers are also responsible for production issues. Larger companies have the resources to separate development and maintenance. However, in this case, production problems and challenges may not reach the development team, and as a result, CAPA practices may not work efficiently. Surprisingly, companies of all sizes report varying degrees of success in managing risk and defects. This may indicate that companies have challenges in implementing well-managed risk management practices.

Table 3. Success of assurance practices in use per company size (%)

| Level of use | Documented processes | CAPA | Roles and responsibilities | Quality acceptance criteria | KPI | Common rules | List of unsolved risks/defects | Separate team solving customer defects |
|---|---|---|---|---|---|---|---|---|
| Small-size companies: <50 | | | | | | | | |
| Not used | 14 | 43 | 18 | 21 | 57 | 11 | 14 | 61 |
| Poorly | 21 | 18 | 18 | 18 | 25 | 11 | 11 | 11 |
| Fairly | 29 | 25 | 29 | 25 | 4 | 14 | 14 | 21 |
| Well | 21 | 7 | 25 | 18 | 4 | 21 | 18 | 4 |
| Very well | 11 | 4 | 11 | 18 | 11 | 18 | 18 | 4 |
| Excellently | 4 | 4 | 0 | 0 | 0 | 25 | 25 | 0 |
| Medium-size companies: 51–250 | | | | | | | | |
| Not used | 5 | 32 | 21 | 21 | 32 | 0 | 5 | 32 |
| Poorly | 11 | 16 | 11 | 26 | 32 | 11 | 21 | 5 |
| Fairly | 21 | 16 | 16 | 21 | 26 | 16 | 26 | 11 |
| Well | 26 | 26 | 21 | 11 | 0 | 37 | 21 | 26 |
| Very well | 32 | 5 | 26 | 11 | 11 | 21 | 26 | 26 |
| Excellently | 5 | 5 | 5 | 11 | 0 | 16 | 0 | 0 |
| Large-size companies: >250 | | | | | | | | |
| Not used | 5 | 24 | 12 | 15 | 20 | 7 | 10 | 29 |
| Poorly | 15 | 20 | 2 | 15 | 12 | 12 | 12 | 10 |
| Fairly | 29 | 17 | 29 | 24 | 32 | 22 | 32 | 22 |
| Well | 32 | 24 | 29 | 37 | 17 | 24 | 22 | 17 |
| Very well | 12 | 7 | 20 | 5 | 12 | 27 | 17 | 15 |
| Excellently | 7 | 7 | 7 | 5 | 7 | 7 | 7 | 7 |

Defined and documented roles and responsibilities (Table 3) are critical to CAPA and assurance practices, with clear differences based on company size. Small companies often lack well-defined roles, while larger companies tend to document them more thoroughly. Similarly, documented processes follow this trend: as companies grow, the need for clear documentation increases. In addition to serving as a learning and communication tool, well-documented processes are essential for quality assurance audits and validation procedures, which require named process owners.

While companies of all sizes report that they perform quality assurance well, the results show varying degrees of success in defining quality assurance criteria (Table 3). Interestingly, even large companies report similar challenges to smaller ones, suggesting that defining and managing quality requirements remains difficult across the IT industry. However, all companies report strong adherence to common rules and practices in their daily software development operations.

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When analyzing how organizations perform assurance practices on a daily basis, in small companies (Fig. 3) practices such as risk management, technical debt management, and software development practices tend to be in the "well" to "excellent" range, but still have a noticeable portion of respondents indicating low application. Clear DoD is a well-implemented practice, while privacy assurance and security assurance are moderately practiced. Testing and quality assurance show room for improvement, with more developers reporting moderate compliance. For medium-size companies, software development practices, security and quality assurance show strong performance, with many IT professionals rating them highly, indicating focus on these areas. Risk management and technical debt management also perform well but show much more variability. Privacy assurance and testing practices have inconsistent results, suggesting that these areas are not consistently prioritized. Use of standards & best practices and clear DoD show moderate performance.

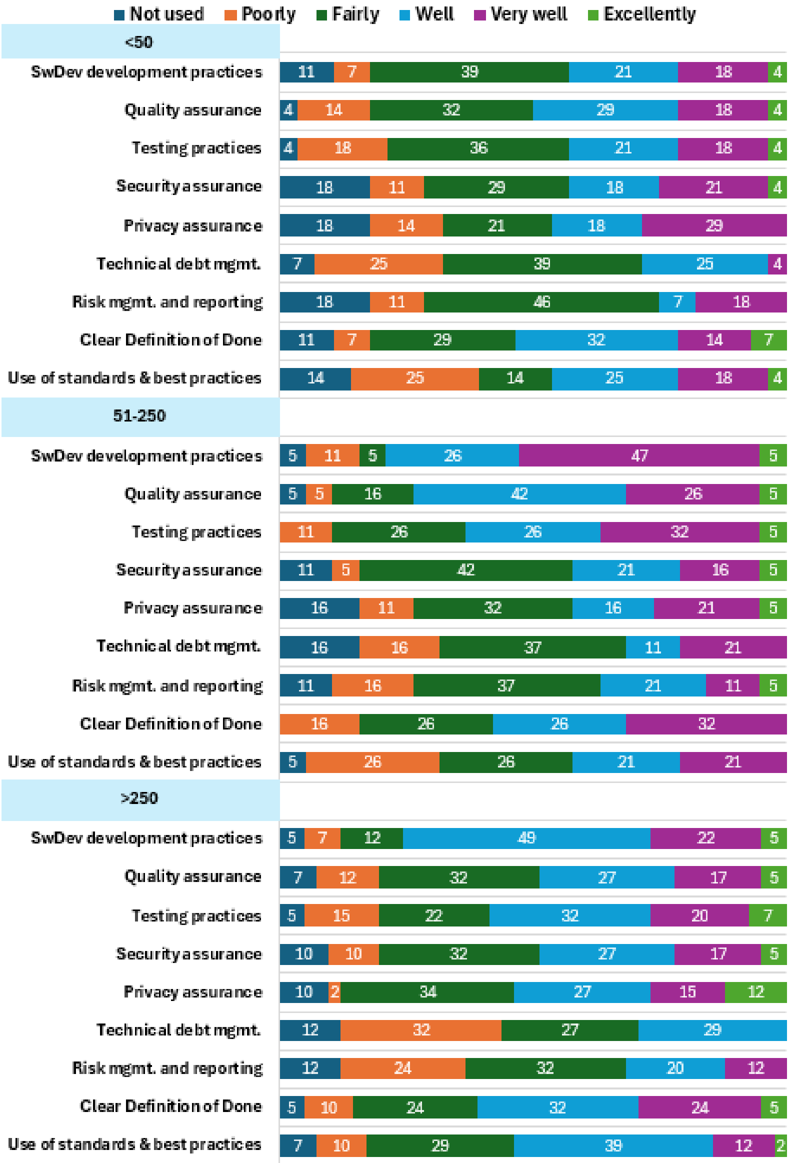


Fig. 3. Performing assurance practices on a daily operation

In large companies (Fig. 3), software development practices, clear DoD, and quality assurance are well practiced. Security and privacy assurance are moderately well practiced, as are testing and the use of standards and best practices, but there is some variability. Technical debt management and risk management show weaker performance. This suggests that these practices are less of a priority or are not implemented or managed efficiently.

*Verification practices.* Verification is one of the most important assurance practices (Fig. 4). When analyzing the "Not used" practices, small organizations rarely use threat assessments and external audits, and have limited use of internal audits, observations, and interviews. Medium-sized organizations also avoid threat assessments and architectural reviews, with moderate avoidance of external audits and observations. Large organizations rarely use external audits, which is a surprising result. They also rarely use observations and threat assessments, architectural reviews and interviews.

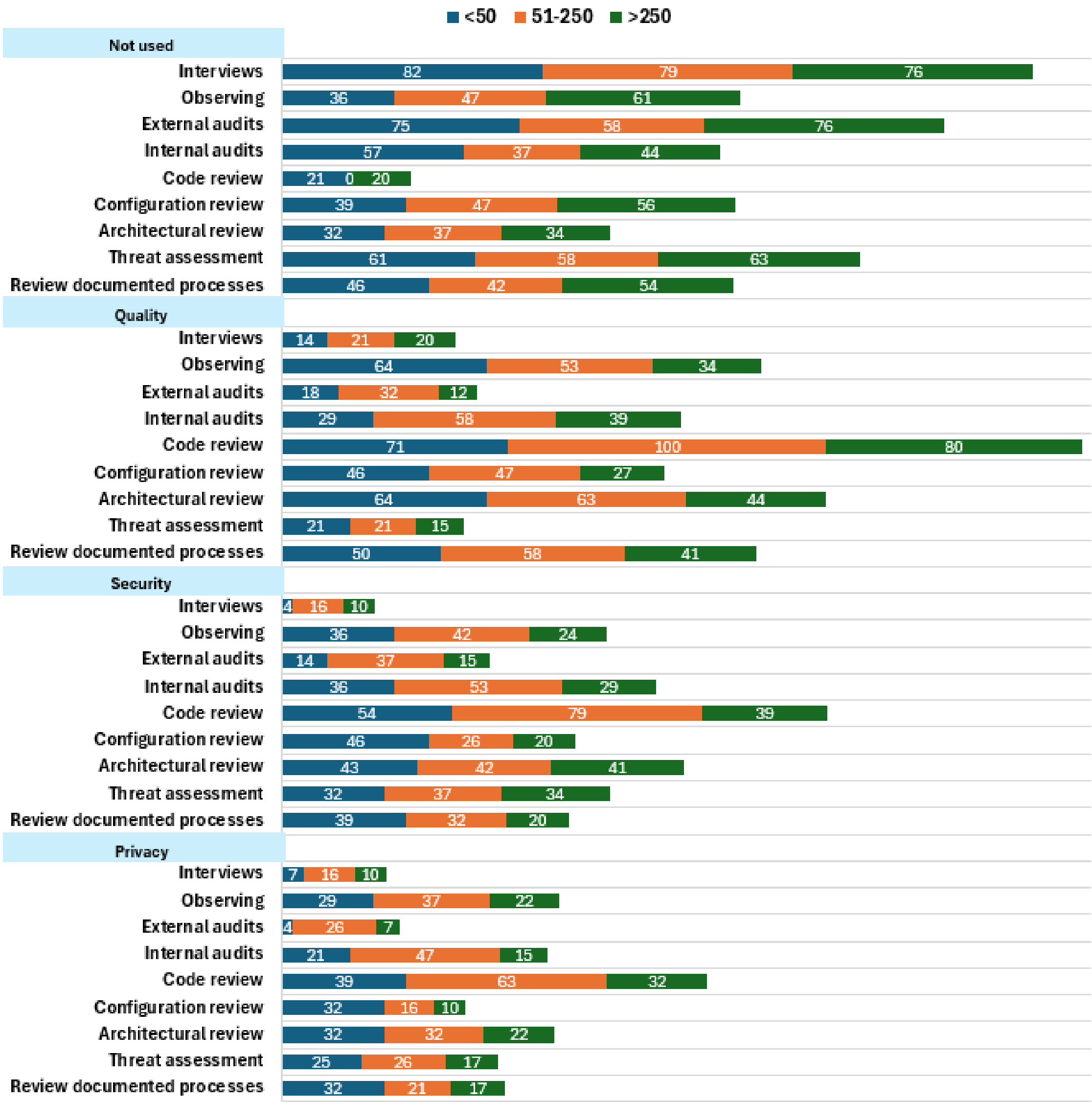


Fig. 4. Verification techniques used during a project for quality, security and privacy (%)

Small companies (Fig. 4) focus primarily on code and architecture reviews and internal audits. For quality assurance, internal audits and observations are common, while architecture reviews and review documented processes are also high priorities. Configuration reviews and code reviews are fairly common, with moderate use of external audits and threat assessments. In security, documented process reviews, threat assessments, architectural reviews, and configuration reviews are well used, showing a strong focus on security design. Internal audits and code reviews are common, but external audits and observations are less common. For privacy, review documented processes and architectural reviews are widely used, with internal audits and code reviews indicating strong internal controls. Threat assessments and configuration reviews are used moderately, while external audits and observations are less common. Interviews are rarely used as a verification practice across all three assurance areas (quality, security, and privacy).

Medium-sized companies (Fig. 4) prioritize internal audits and architectural reviews for quality assurance. Documented process reviews, external audits, observations, and configuration reviews are also common. For security, internal audits and threat assessments are highly prioritized, and external audits and observations are common. Code reviews are less emphasized, and interviews are rarely used. For privacy, internal audits and code reviews are main practices, while observations, review of documented processes, and threat assessments are less emphasized. External audits are used moderately, and interviews are a lesser verification practice for quality, security, and privacy.

For quality, large companies (Fig. 4) consistently use internal audits, architectural reviews, and review of documented processes, while surprisingly code reviews, threat assessments, and observations are less emphasized. For security, internal audits and threat assessments are commonly used. External audits, configuration reviews and observations are used moderately. For privacy, internal audits and architectural reviews are used, but less consistently than in smaller organizations, while review documented processes and threat assessments show limited use. External audits and observations are infrequent, indicating a lower priority, and interviews are used the least, similar to smaller organizations.

*Post-delivery challenges.* Analysis of the post-delivery results for all company sizes (Fig. 5) shows that many respondents chose "no answer," likely due to lack of knowledge (large companies represented over 40 % of respondents), especially in larger companies where maintenance teams handle post-delivery issues.

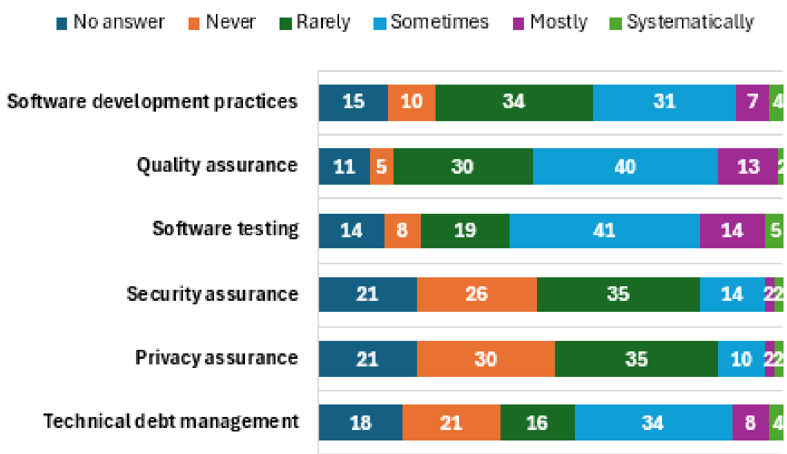


Fig. 5. Post-delivery challenges (%)

The results in Fig. 5 and the open-ended responses show that post-deployment challenges are primarily related to quality assurance and testing (60 %), indicating that gaps in these areas/assurance practices during development lead to problems in production. Software development practices also contribute to post-delivery problems (40 %), indicating that deficiencies in these practices affect production stability. In addition, technical debt is identified as a source of production problems, highlighting the need for proactive management. In particular, security and privacy issues appear post-delivery in over 50 % of cases, suggesting that these areas may lack robust assurance practices during development, which are often addressed reactively ("band-aid" solutions) when problems arise. This could indicate insufficient proactive measures or a lack of prioritization of security and privacy during the development phase. Overall, these findings suggest that insufficient focus on quality, security, and privacy assurance during development leads to many post-delivery challenges.

## 5. Discussion

This section discusses the results of the study and is divided into five sections. First, Section 5.1 discusses assurance practices in day-to-day operations. Section 5.2 focuses on the challenge of using fixed practices in a continuous improvement environment. Section 5.3 examines the role of education and universities in integrating assurance practices into educational content and shaping culture. Section 5.4 provides theoretical and managerial perspectives on this study, and Section 5.5 outlines the limitations of the study.

### *5.1 Assurance practices in daily operations*

To deliver business value and retain customers, organizations must be able to produce high-quality, secure, and privacy-compliant products. Assurance practices play an important role in ensuring that these requirements are successfully addressed as part of the software development lifecycle. However, the assurance practice survey shows that companies have not fully implemented assurance practices to realize the full benefits of well-implemented assurance management. The survey results show that companies are primarily focused on software development and ensuring that the necessary requirements are in place. This focus is critical because the business demands results and products that create value for both the business and its customers. Achieving this value is only possible through effective software development, namely delivering high quality products. This is clearly reflected in the results, where the most important practice identified is adherence to software development practices.

When analyzing the success of companies in implementing assurance practices, most of the focus has been on implementing quality and testing practices as part of daily operations. Our findings on the importance of quality assurance are consistent with Deshpande et al. (2023), who also emphasize its critical role in daily operations. In contrast, security and privacy practices were quite inconsistent, giving the impression that these aspects are addressed when something negative happens. Thus, unlike Wong et al. (2022) who found that security practices are well integrated, our study reveals inconsistencies in the implementation of security practices. Our findings suggest that privacy assurance practices are still in their infancy, which is consistent with the observations of Presthus & Sørum (2024). This may indicate that security and privacy, in particular, are considered separate from software development, and that implementing these aspects in daily operations is more challenging than quality practices. However, many security-related tests rely heavily on manual testing, and therefore security-related automation does not provide benefits as quickly as quality-related test automation. A very typical solution for companies is to always use the same set of predefined practices, and these same practices are used regardless of the customer, the project, or the situation. Companies also tend to leave compliance as a project responsibility.

However, if you stick to one method for a long time, you will not improve. And this goes against the current de facto approach in software development, which is to use agile practices. Our study extends the work of Haider & Bhatti (2022) by highlighting the challenges of integrating security practices in agile environments. Agility thrives on change, uses iterative and flexible processes, and focuses on continuous improvement that evolves as the project progresses. The core of agile practices is to reflect on the work, practices, and processes after each iteration and identify ways to improve. If teams always use the same set of practices, this process becomes ineffective because they do not adjust their approach based on lessons learned or evolving project needs. Sticking to a fixed set of practices inhibits the ability to adapt to changing needs and contexts, making it fundamentally incompatible with the agile approach. There is no one-size-fits-all assurance practice. Different industries, regulatory requirements, and project types may require different assurance practices.

An important aspect that is often overlooked is the lack of alignment between organizational priorities and the actual implementation of assurance practices. As noted in this study, while organizations recognize the importance of assurance practices, there is a gap between their recognition and practical integration. This gap may be due to competing priorities, such as the pressure to deliver results quickly or meet tight deadlines, which often take priority over embedding comprehensive assurance practices in day-to-day operations. The organizational mindset may still treat assurance practices as a compliance requirement rather than a strategic enabler of long-term business value. This mindset not only limits the potential benefits of assurance practices, but also hinders innovation, as teams may resist change or fail to adopt more effective practices that could address evolving needs. For organizations, addressing this strategic misalignment is critical to transforming assurance from a peripheral activity to a core element of software development.

*5.2 The challenge of fixed practices vs. the need for continuous improvement*

The study shows that the importance of effective and well-managed assurance practices in software development is well recognized and understood. So why, despite the best efforts of IT professionals and companies, do assurance practices not become an integral part of daily operations? Why do they remain as separate activities? Several factors are likely contributing to this challenge.

There may be resistance to implementing comprehensive assurance practices because they are not seen as critical by senior management. Without management support, it is difficult to implement assurance practices consistently. This is also often justified by the inflexibility of assurance practices, which are seen as development bottlenecks that limit product implementation by introducing external constraints and requirements (such as various compliance requirements) through often structured, process-heavy approaches. This tension between agile iteration and formal assurance can make it difficult to consistently embed comprehensive quality, security, and privacy assurance practices throughout the development process. Documenting processes for assurance practices can be a pain point, especially in large organizations. The need for detailed process documentation and compliance checks can feel overwhelming, and some teams may neglect it in favor of shorter, more agile workflows.

Assurance practices are often seen as a separate task that adds cost, and paying attention to assurance issues takes resources and prevents things from being done "easily" or efficiently because of (perceived) marginal problems. As a result, assurance practices are seen as an added cost rather than a value-added activity, often deprioritized by developers to meet tight deadlines or budgets. Development teams focus on adding new features and meeting deadlines, while assurance teams focus on risk mitigation, defect detection, and regulatory compliance. These priorities can conflict, especially when development teams are under pressure to release quickly.

Quality assurance practices such as comprehensive testing, security testing, and compliance checks require significant time and resources, which can slow down the development process. While Nakahara et al. (2021) suggest that code review can reduce testing effort, our findings indicate that comprehensive testing remains essential for quality assurance. Effective quality and security assurance requires skilled professionals, which can be a challenge, especially in smaller organizations. For example, new vulnerabilities and threats emerge regularly, making it challenging to maintain security throughout the software lifecycle. With the rise of cloud computing, microservices, and third-party integrations (e.g., leveraging digital supply chains), ensuring quality and security has become more complex. Assurance practices must account for multiple platforms, technologies, and environments, making it difficult to maintain consistency and coverage.

The growing importance of security assurance is consistent with Haider & Bhatti (2022), who emphasize the integration of cybersecurity into quality assurance testing. Unlike Khan et al. (2022), who examine various security testing methodologies, this study highlights inconsistencies in implementation of security practices, suggesting that companies are taking a reactive rather than proactive approach.

This study identified quality assurance as the most emphasized practice, consistent with Deshpande et al. (2023), who emphasize its critical role in day-to-day operations. While Wong et al. (2022) emphasize the importance of testing techniques, our findings suggest that companies often adhere to predefined practices rather than tailoring them to specific project needs. Using the same practices helps companies standardize processes across the organization, making it easier to manage and maintain assurance requirements. It is also easier to sell and convince customers of the company's assurance practices. This approach creates a predictable and repeatable workflow to follow. It also saves time because customization requires additional effort in planning, training, and adapting practices. Using familiar practices can also be seen as a form of risk management. The practices may not be perfect, but they have been tested and refined over time. These familiar practices provide a safety net. When an organization has experienced success with a set of practices, it is less likely to experiment with new methods that could lead to errors or disruptions in workflow. And when a set of practices is seen as a working approach, there is no rush to add or improve it, even if companies are not able to reap all the benefits of well-implemented assurance, especially if they do not see an immediate benefit from changing or expanding current practices. For example, customers are unlikely to pay for reporting on supplier quality metrics.

### *5.3 Educational shift for assurance practices*

Given the challenges in successfully implementing assurance practices, what can be done to address them? Often it is a cultural aspect that needs to be changed, and that change starts with IT education. Different IT practices and viewpoints are indoctrinated during IT studies, and if assurance practices are seen as separate silos rather than core software development skills and practices, change is almost impossible. Improving software development practices requires early and integrated approaches to assurance that are progressively introduced in courses.

Seamless integration of quality, security and privacy into the software development lifecycle means incorporating these aspects from the beginning and using automated tools for continuous testing and monitoring. An example is the "Shift Left" approach, where the goal is to integrate security early in the development lifecycle (security reviews, threat modeling and vulnerability scanning during design; TDD and CI/CD approaches to ensure quality is built in). This study's identification of the role of education in integrating security practices is consistent with the Shift Left approach, which emphasizes early and proactive security measures. Essential skills include automated testing and CI (TDD, automated security scanning: Static Application Security Testing, Dynamic Application Security Testing, and Software Composition Analysis), and embedding security in agile practices, such as learning how to embed security practices in agile development practices like DevSecOps. Or learn that effective assurance involves Sprint planning with quality, security, and privacy in mind, using a DoD that requires unit testing, code reviews, security checks, and privacy compliance before completion. It is important to learn to use metrics to track the effectiveness of assurance practices. If metrics are not introduced and practiced during studies, it is difficult to understand their value.

While universities play a key role in preparing students for software development, the curriculum often lags behind industry needs, especially in areas such as security and privacy. This mismatch between academic preparation and real-world demands leaves graduates unprepared to address security or privacy challenges in real-world scenarios. The lack of a consistent framework that incorporates both theory and industry needs for evaluating the success of integrating quality, security, and privacy into educational content limits the ability to identify gaps and improve integration. Although integration of these topics ensures that graduates are better prepared for real-world demands, many IT curricula still treat privacy and security as peripheral or advanced topics rather than core competencies. This separation reinforces the misconception that quality, security and privacy practices are optional or secondary to software development. However, the rapid evolution of threats, technologies, and regulations is creating a gap between academic knowledge and practical requirements, making it difficult for universities to keep their programs aligned with real-world needs. Another challenge is balancing theoretical knowledge with practical experience. While students may learn about general security or privacy principles or compliance frameworks, they often lack exposure to practical tools such as automated testing, threat modeling, or CI/CD pipelines. This study highlights the importance of practical tools and metrics, yet the literature suggests that universities often lag behind industry needs in these areas. The interdisciplinary nature of security and privacy at the intersection of law, ethics, and business is often overlooked in IT programs, limiting students' ability to address complex, multifaceted challenges.

This raises the question of how well university programming and software development courses incorporate assurance practices. It would be valuable to examine the extent to which these courses prepare students to view quality, security, and privacy as integral to the development process, rather than as isolated silos or checklists. In addition, exploring faculty perspectives could reveal whether certain attitudes or traditional approaches may unintentionally hinder the shift toward viewing assurance as a core component of software development. Understanding these dynamics could provide insights into how educational programs might evolve to produce graduates who are ready to seamlessly integrate assurance into their work and thereby drive change in organizational practices.

### *5.4 Theoretical and Managerial perspectives*

*Theoretical perspective.* This study contributes to the theoretical understanding of assurance practices in the context of software development by exploring how quality, security, and privacy frameworks are adopted, applied, and performed throughout the software development lifecycle. By surveying 88 software professionals in Finland, the research provides empirical insights into the challenges and inconsistencies developers face in integrating assurance practices. The findings highlight the tension between the flexibility of agile methodologies and the rigidity of traditional assurance practices, emphasizing the need for a more integrated and adaptive approach. The study also draws attention to the underemphasis on security and privacy assurance compared to quality practices, suggesting that these areas are often addressed reactively rather than proactively. This research extends the theoretical discourse on the role of assurance in software engineering by advocating a seamless approach that incorporates quality, security, and privacy assurance from the early stages of development, rather than as an isolated or final activity. It also contributes to the conversation about the educational gaps in preparing software developers to integrate assurance practices as a core competency.

This study revealed practices that were consistent with the literature review. As shown in Table 1, quality remains the highest priority, with 80 % of the reviewed papers and the survey results of this paper emphasizing its importance in daily operations. Security follows, addressed in 50 % of the literature and reflected in operational practices in the survey, although it has not yet reached the same level of maturity as quality. Privacy practices were still in the early stages, with efforts focused on defining and establishing daily practices, consistent with findings in the literature. However, privacy practices are expected to evolve rapidly and reach the same level of importance as security.

According to Alvesson & Sandberg (2011), Avison & Malaurent (2014) and Gregor (2006), theory building involves a systematic approach that integrates problematization, practical relevance, and structured frameworks. Alvesson and Sandberg (2011) emphasize the problematization of assumptions in existing research in order to generate innovative questions. Avison & Malaurent (2014) argue for balancing theoretical contributions with real-world applicability to ensure practical impact. Gregor's (2006) taxonomy provides a framework for theory building, whether for analysis, explanation, prediction, or design and action. The findings of this study problematize the reactive nature of quality, security, and privacy assurance and highlight the tension between the need for the flexibility of agile methodologies and the rigidity of traditional assurance frameworks. This research challenges established assumptions and supports an integrated, proactive approach to assurance that is consistent with agile principles and modern development needs. Balancing theoretical rigor with practical relevance, this research extends the theoretical discourse by providing actionable insights, such as embedding assurance practices from the earliest stages of development and addressing educational gaps that prevent the seamless integration of these practices as core competencies. This study contributes by proposing adaptive and integrated assurance practices that enable software professionals to meet current challenges. By bridging theoretical concepts with practical implications, this research provides both a deeper understanding of assurance practices and concrete ways to improve them in agile and iterative development contexts.

*Managerial perspective*. From a managerial perspective, this study provides valuable insights for organizations seeking to improve their software development practices by embedding assurance methodologies into daily operations. The findings suggest that while organizations recognize the importance of quality assurance, many still struggle to implement security and privacy practices effectively, often treating them as secondary concerns or addressing them reactively when problems arise. These findings aim to bridge the gap between theoretical knowledge and practical application by fostering a culture of continuous improvement where assurance practices are seamlessly integrated into the development process. The study highlights the need for a balanced approach that combines the flexibility of agile methodologies with the structured, process-driven requirements of assurance. For organizations struggling to adopt comprehensive assurance practices, the research suggests the use of automated tools and continuous monitoring to reduce manual effort and streamline testing procedures. In addition, the study underscores the importance of fostering strong management support for assurance practices and aligning these practices with business goals to ensure that they are not perceived as obstacles, but as value-added activities that are essential to producing secure, high-quality products. The study also highlights the need to include assurance practices as part of educational content to make quality, security and assurance practices core IT competencies.

Organizations need to view assurance practices as integral components of business value creation, rather than as isolated tasks. This study underscores the importance of embedding assurance into daily operations by aligning it with strategic objectives to ensure that it supports both organizational goals and customer expectations. Organizations should take a proactive approach to security and privacy, integrating it as a core element of quality assurance rather than a reactive afterthought. By leveraging automated tools, continuous monitoring, and agile-compatible assurance practices, organizations can reduce manual effort and increase efficiency. Strong leadership support is critical to fostering a culture where assurance is seen as a strategic enabler, not a hindrance. Integrating assurance practices into education ensures that future IT professionals are equipped with the skills necessary to seamlessly integrate quality, security, and privacy into software development workflows, bridging the gap between academia and industry needs.

### *5.5 Limitations*

Naturally, it is recognized that this research has limitations. We recognize that the typical literature review is conducted prior to actual research, such as a survey (as in Webster and Watson, 2002). Because quality assurance practices are well known and well researched, we conducted the literature review using the most recent research available at the time of the survey data analysis, rather than limiting the timeframe to before 2020. Thus, the findings and categorizations from the most recent study were used to structure the review of the survey results and the analysis. The data and examples are drawn from surveys with limited response. All results are based on data from Finland, and country-specific differences may affect applicability. Several measures were taken in the preparation, design, and implementation of the survey and in the analysis of the data to reduce or avoid threats to the validity of the study. The survey instrument was an open and anonymous questionnaire, which posed challenges such as the inability to identify the respondents' place of residence, institution, company or project. Recognizing that the respondents have the same or very similar educational background, possibly even having graduated from the same institutions; the respondents work in the software development industry, share their experiences, and draw from the same practical influences. The target group to which the survey was sent and advertised was selected from an extensive list of Finnish software companies and well-known actors in the industry. The respondents were involved in different activities in software development projects. Thus, generalizing the results from the observed sample to all IT professionals would lead to potentially misleading results, and therefore descriptive statistics were used to present the results in order to avoid issues in external validity. The results provide valuable insights that can be generalized to similar contexts and inform improvements in assurance practices in both industry and academia.

## 6. Conclusion

The purpose of this paper was to examine the order in which software developers follow assurance practices, how systematically they use the same set of practices, the compliance with regulations, and the success of implementing quality, security, and privacy assurance in daily operations. The results show that IT professionals place the greatest emphasis on software development practices, recognizing the role of quality assurance and testing in producing quality products. However, security and privacy practices appear to be less consistently implemented, suggesting that they are often treated as separate from daily practices. This underscores the need to integrate assurance practices more closely into routine operations, rather than as isolated tasks that are addressed only reactively. Addressing this gap starts with IT education, where curricula could evolve to introduce frameworks that embed quality, security, and privacy at the core of software development. This could prompt universities to evaluate their course content and provide students with a stronger foundation in assurance practices.

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International Journal of Information Systems and Project Management (IJISPM)
2026, 14(1), e140103, DOI: 10.12821/ijispm140103

RESEARCH ARTICLE

# Designing a fitting hybrid project management approach: a contingency perspective

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**Abstract**
The hybrid approach in project management is now considered as a leading project management approach, that is applied in the majority of projects. However, the hybrid approach, which is defined as the combination of the predictive and adaptive approaches, is also still emerging, with several challenges and issues showing from literature. One of these issues is that the definition of hybrid as a combination of adaptive and predictive approaches leaves room for interpretation and variation. Hybrid is a spectrum of different ways of planning, controlling, organizing, leading and performing a project, that needs to be tailored to the situational circumstances. It is this tailoring process that the study focuses on. Based on the criteria for assessing the fit of an approach, the study identified the following six hybrid approaches, 'Flexible predictive'; ''Tolerant predictive'; 'Predictable adaptive'; 'Adaptive light'; 'Integrated hybrid' and 'Facilitated adaptive'. By applying a contingency approach to the design of a hybrid approach, the study aims to contribute to the further development of the understanding of hybrid project management.

**Keywords**
hybrid project management; project management approach; adaptive; predictive; agile.

Received: 9 August 2024 | Accepted: 30 April 2025

## 1. Introduction

The publication of the Agile Manifesto (Beck et al., 2001) provides a milestone in the development of more adaptive approaches to software development, compared with the structured sequential methodologies of the 1980's and 1990's, which are now considered a 'waterfall', or predictive, approach (Gemino et al., 2021). In the adaptive approach, the product or system is developed in short iterative development cycles, thereby reducing the need for a complete and detailed description of the user's requirements, at the start of the development process (Reiff & Schlegel, 2022). Adaptive methodologies allow for a 'just-in-time' freezing of requirements during the development process (Timinger, 2017), which allows for an easier absorption of changes in these requirements, leading to an increased satisfaction of future users, project sponsors and other stakeholders (State of Agile, 2022). Other aspects of these methodologies, such as increased transparency and intensified communication, also contribute to the perceived success of agile methodologies.

However, with the wide adoption of the adaptive approach and agile methodologies, also their disadvantages appeared (Reiff & Schlegel, 2022). For example, a lower level of predictability of what output will exactly be delivered, at which moment in time, and against which costs (Laux & Kranz, 2019). In order to overcome these disadvantages, but to keep the advantages of adaptiveness, the approaches got mixed into what is considered a 'hybrid' approach (Cooper & Sommer, 2018). Hybrid refers to "*a combination of adaptive and predictive approaches*" (Project Management Institute, 2021:36), which implies that some elements from a predictive approach are used and some from an adaptive approach are used. A recent study showed that "*hybrid is a leading project management approach*" (Gemino et al., 2021; Kuhrmann et al., 2022), that is used in "*by far, the majority of projects*" (Serrador & Pinto, 2015).

Despite this apparent popularity, the "*ideal*" structure of hybrid projects remains underexplored (Karvonen et al., 2018; Bianchi et al., 2020). The hybrid approach is still an emerging approach (Gemino et al., 2021) that "*should be further investigated*" (Serrador & Pinto, 2015). Most existing literature concentrates on the characteristics, advantages, and disadvantages of specific hybrid models (Krupa & Hájek, 2024) or offers general overviews of the hybrid approach (Reiff & Schlegel, 2022; Zasa et al., 2021), yet they leave unexplored how organizations use this approach (Krupa et al., 2024). The definition of hybrid as a combination of adaptive and predictive approaches (Project Management Institute, 2021:36) leaves room for interpretation and variation. In the latest "*Pulse of the Profession*" report, PMI positions the hybrid approach as a spectrum of different ways of working (Project Management Institute, 2024). From a primarily predictive approach that utilizes some agile practices, to a primarily adaptive approach, that uses planning to improve the predictability of deliverables, budgets and timelines. And despite the growing number of studies on hybrid and hybrid methodologies, the issue of how organizations can overcome the challenges arising from the coexistence of the adaptive and predictive approaches remains an open issue (Zasa et al., 2021).

Hybrid is not a clearly defined methodology, but a combination of approaches that require tailoring to the situational circumstances of a specific project (Lalmi et al., 2021). This presents a challenge for organizations that seek 'the best of both worlds' in hybrid (Reiff & Schlegel, 2022) but lack insights and guidance from literature to choose or design a form of hybrid that fits the project at hand. It is this gap in the literature that the study reported in this paper focuses on. Based on the criteria that determine the suitability of the predictive, adaptive or hybrid approach, the study aims to develop a typology of scenarios in which a hybrid approach would be called for, and to design a form of hybrid that fits each scenario. The research question of the study is formulated as *Which design choices in a hybrid approach fit the situational characteristics of the project and its environment?* The study aims to contribute to the further understanding of hybrid project management, by applying a contingency approach to the design of a 'fitting' hybrid approach.

The remainder of the paper is structured as follows. The following section will provide a compact overview of the different approaches to project management, predictive-adaptive, and will identify the design elements of an approach that can be mixed into a hybrid approach. The section will also discuss the criteria for assessing the applicability of the approaches, as summarized by Silvius-Zuchi and Silvius (2024b). Based on the model that this study developed for assessing the suitability of the approaches, six scenarios in which a combination of the predictive and adaptive approaches would be most fitting, will be identified. These six scenarios that would call for some kind of hybrid approach are then further developed in a study, in which six different hybrid approaches are designed. The paper will be concluded with a discussion and suggestions for further work on this topic.

## 2. Literature review

For the literature review, we used Google Scholar, as "*researchers should consult Google Scholar ..., especially for a relatively recent article, author or subject area.*" (Bauer & Bakkelbasi, 2005). And although there is a debate in the scientific community on the use of Google Scholar as an academic database (Henderson, 2005), it is also considered to provide "*unique options*" (Falagas et al, 2008: 342) to the academic community. Search strings used were based on the keywords "hybrid project management", "agile project management", "adaptive project management", "predictive project management", as well as their combinations. We followed Clark et al. (2019) in applying the inclusion and exclusion criteria summarized in Table 1.

Table 1. Literature Inclusion and Exclusion Criteria

| Inclusion criterion | Description |
|---|---|
| Primary source | Literature collated and interpreted directly |
| Relevant topic | Direct reference to research area |
| Literature hypothesis / proposition quality | Testable hypothesis or demonstrable proposition, which can be evaluated |
| Methodology quality | Research methodology included and applied |
| Data quality | Data is relevant and sources are traceable |
| Outcome quality | Evidence between gathered data and analysis results is transparent |
| **Exclusion criterion** | **Description** |
| Secondary source | Information can distort analysis |
| Irrelevant topic | Literature focuses on another topic or utilizes the key words with another intention |
| Inadmissible quality | Untestable information and/or inadequate documentation |
| Unavailability | Literature was/is not available in data sources |
| Language duplication | Literature is a duplicate of other used literature |

### *2.1. Project management approaches*

In general, an approach stands for "*a way of dealing with a situation or problem*" (Cambridge dictionary, 2024). When applied to project management, an approach is the highest level of concepts used "*when describing how a project will be designed and governed*" (Gemino et al., 2021). It suggests "*a set of principles and guidelines which define the way a specific project is managed*" (Špundak, 2014). An approach should not be confused with a specific methodology for project management, or a method/technique, such as a Kanban board or planning poker. An approach provides directions for methodologies and/or methods that can be developed to fit within the principles of the approach.

The predictive and adaptive approaches have been characterized and contrasted by several authors (For example Thesing et al., 2020; Silvius-Zuchi & Silvius, 2024a). Table 2 summarizes this characterization of the approaches. The hybrid approach is not included in this table, as this approach is in general defined as the combination of the two abovementioned approaches (Project Management Institute, 2021), and it is the aim of our study to provide more specific insights into the potential combinations.

The variables that are used in Table 2 to characterize the approaches, can be considered as the elements by which an approach can be designed. Based on the literature (For example Kanski et al., 2023; Thesing et al., 2020; Zasa et al., 2021; Silvius-Zuchi & Silvius, 2024a), we identified six 'design elements' of an approach: Development process, Planning philosophy, Controlling philosophy, Leadership style, Communication style, and Team organization. In the following section, the characterization of the predictive and adaptive approaches on the six design elements is further clarified.

- Characteristic of the adaptive approach is the organization of the *development process* in multiple, even many, development cycles (Beck et al., 2001). The predictive approach is based on a single development cycle, although multiple development cycles can also appear in case the developed product has a modular architecture. As in the adaptive approach, the requirements of the product are detailed and 'frozen' just-in-time before the development of that part or function of the product (Smith, 2008), the adaptive approach is less vulnerable for changes in requirements. Distinguishing between minimal and optional requirements for the products is also an essential practice in the adaptive approach (Smith, 2008).
- In the adaptive approach, the *planning and controlling philosophy* is product oriented, with the product backlog as a central method (Reynisdottir, 2013). This contrasts the more activity oriented planning and controlling philosophy of the predictive approach, in which the Work Breakdown Structure plays a central role (Silvius-Zuchi & Silvius, 2024a). In the adaptive approach, controlling of the social aspects of the project is integrated in the development process, by organizing regular reflections in order to stimulate learning (Paasivaara et al., 2008). In the predictive approach, the controlling of the social aspects of the project is very much depending on the leadership style of the project manager.
- *Leadership* in the adaptive approach is often characterized as humanistic in that it regards people as skilled and valuable stakeholders in the management of a team (Parker et al., 2015). An agile leader can cope with not knowing the detail (McPherson, 2016), and can quickly get to grips with complex issues and ask the right questions. In the adaptive approach the leadership style can be characterized as transformational, participative and servant, whereas the predictive approach is often expected to have a more planning and control oriented transactional leadership style (Parker et al., 2015). Although the leadership style of 'predictive' project managers should not be generalized as being just task-oriented, as the results of several studies show that managers of projects showed both task-oriented leadership and relationship-oriented leadership behaviors (Henkel et al., 2019).
- In the adaptive approach, the preferred *mode of communication* is face-to-face, with if possible co-location of teams (Beck et al., 2001). This also applies to the communication between developers and (future) users, with when possible the inclusion of user representatives in the development team (Burns & Evans, 2000; Reynisdottir, 2013). Resulted from the methodologies of software development developed in the last decades of last century, the predictive approach relies on documented descriptions of user requirements, that emerge throughout the development process. The intensive communication in the adaptive approach also contributes to the transparency of the development process and progress (Ahmad et al., 2013), which in the predictive approach is less eminent.
- The adaptive approach allows for some level of self-*organization* in (sub-)teams within the project organization (Ovesen, 2012), with dedicated roles to support this self-organization (For example, a Scrum master or Agile coach), and to make sure that the team is working on the 'right' things (For example, a Product owner). This last role, the Product Owner, is also empowered to make decisions about the priorities of requirements, thereby

increasing the efficiency of the development process. In the predictive approach, decisions about requirements and changes often require project sponsor or board approval, making the process less effective.

Table 2. Overview of the design elements of the predictive and adaptive approaches in project management

| Design element | Predictive approach | Adaptive approach | References |
| --- | --- | --- | --- |
| Development process | One, or a few, development cycles | Many short development cycles | Aram & Salipante (2003); Carroll et al. (2013); Henkel et al. (2019); |
| | Defining the total set of requirements at the start of each development cycle | Defining and prioritizing requirements as late as possible in the development process | Burns & Evans (2000); Cannella & Paetzold (1994); Carroll et al. (2013) |
| | Inspection of quality primarily at the end of the cycle | Continuous inspections of quality | Carroll et al. (2013); Henkel et al. (2019) |
| Planning philosophy | Detailed upfront planning, activity based | High level planning, output based | Aram & Salipante (2003); Carroll et al. (2013); Henkel et al. (2019) |
| | Upfront estimation of budget and duration | High level estimation of budget and duration | Cannella & Paetzold (1994); Carroll et al. (2013); Henkel et al. (2019) |
| Controlling philosophy | Upfront decision making on budget and duration | Rolling decision making on budget and duration | Aram & Salipante (2003); Carroll et al. (2013); Henkel et al. (2019) |
| | Controlling of budget and duration | Controlling of output | Cannella & Paetzold (1994);Burns & Evans (2000); |
| | Possibly also 'social' controlling to facilitate team development and learning | Frequent reflection moments ("retrospectives") to facilitate team development and learning | Cannella & Paetzold (1994) |
| Leadership style | Transactional and/or Servant | Transformational, Participative and Servant | Ahmad et al. (2013); Burns & Evans (2000); Cannella & Paetzold (1994) |
| Communication style | Primarily documentation based | Primarily conversation based | Aram & Salipante (2003); Burns & Evans (2000); Cannella & Paetzold (1994); Henkel et al. (2019) |
| | Limited level of transparency | High level of transparency | Cannella & Paetzold (1994); Carroll et al. (2013) |
| Team organization | Functional-hierarchical | Self-organization | Ahmad et al. (2013); Aram & Salipante (2003); Cannella & Paetzold (1994); Henkel et al. (2019) |
| | Strategic level decision making on requirements and changes | Operational level decision making on requirements and changes | Cannella & Paetzold (1994); Carroll et al. (2013 |
| | Support of the team depending on leadership style | Inclusion of a coaching role supporting the team | Ahmad et al. (2013); Cannella & Paetzold (1994); Henkel et al. (2019) |

International Journal of Information Systems and Project Management (IJISPM)
2026, 14(1), e140103, DOI: 10.12821/ijispm140103

By considering an approach as something that should be situationally designed, we underline the active role of the project manager in the project management approach (Silvius-Zuchi & Silvius, 2024b). A project management approach should not be something that 'happens' to the project manager, but a deliberate design choice (Gemino et al., 2021). As a hybrid approach combines the predictive and adaptive approaches, it will inevitably mix up the design choices on the elements described above. Designing a hybrid approach is therefore about making choices on the different design elements above (Marnewick & Marnewick, 2023). And as a project manager should design an effective approach for the project at hand (Gemino et al., 2021), the project manager should make an adequate set of design decisions on these elements, taking into account the situational circumstances of the project.

### *2.2. Situational criteria*

The situational criteria that should be considered when selecting or designing the most suitable approach for a project, have been the subject of several publications (For example Thesing et al., 2021; Zasa et al., 2021; Silvius-Zuchi & Silvius, 2024b). And although these publications differ slightly in the criteria they identify, a common denominator can be found in three categories of criteria: Product-related criteria, Organization-related criteria and Team-related criteria. Product-related criteria refer to the characteristics of the deliverable that the project should realize. For example the definition and stability of the requirements, the coherence of its overall design, and whether the development methods are known. Organization-related criteria refer to the environment or organizational context of the project, such as the requirements for the governance of the project, and the organizational culture. Team-related criteria refer to the team members and organization. For example their experience and maturity in self-organization. Silvius-Zuchi & Silvius (2024b) summarize these criteria in a model that project owners and managers can use by assessing their project (Figure 1). Based upon the assessment of a project, project owners and managers can determine the appropriateness of the predictive or adaptive approaches.

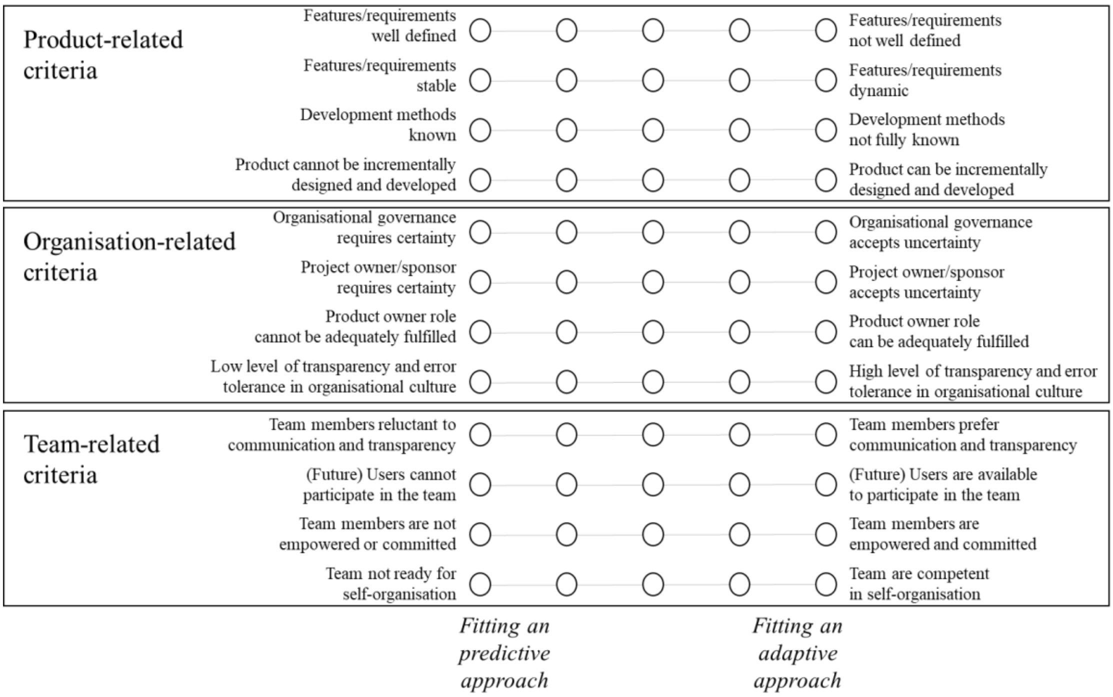


Fig. 1. Overview of criteria for assessing the applicability of the predictive and adaptive approaches (Silvius-Zuchi & Silvius, 2024b).

The model in Figure 1 suggests that when a project scores predominantly on the left side, a predictive approach is fitting, whereas when a project scores predominantly on the right side, an adaptive approach is fitting. When a project, however, shows a mixed score on the left and right sides on the model, a fitting hybrid approach should be designed.

### *2.3. The hybrid approach*

Hybrid project management is an emerging approach in project management practice and literature (Gemino et al., 2021). In a recent overview of the literature on the hybrid approach, Reiff & Schlegel (2022) selected 34 papers for their structured analysis of what defines hybrid project management, its benefits and challenges, and the factors that influence its suitability. Their findings indicate that hybrid is understood in different ways. In the introduction, we have referred to the Project Management Institute's definition of hybrid: "*a combination of adaptive and predictive approaches*" (Project Management Institute, 2021). This combination of the predictive and adaptive approaches can take many shapes and forms. And, as already mentioned in the introduction, the ideal form of hybrid is not developed yet (Karvonen et al., 2018; Bianchi et al., 2020), and the hybrid approach "*should be further investigated*" (Serrador & Pinto, 2015).

In an attempt to provide a typology of hybrid approaches, Timinger (2017) distinguishes a sequential hybrid approach, a parallel hybrid approach and an integrated hybrid approach. In a sequential hybrid approach, one or more phases in the project are performed in an adaptive approach, while the other phases are performed with a predictive one (Silvius-Zuchi & Silvius, 2024b). Examples of this approach are the "*Water-Scrum-Fall*" (West et al., 2011) and "*Waterfall-Agile*" (Hassani et al., 2018) methodologies. In a parallel hybrid approach, some of the project's deliverables are developed with a predictive approach, and in parallel other parts are developed with an adaptive approach (Timinger, 2017). An integrated hybrid approach would be one in which "*the development team works in an adaptive way, but with defined results that need to be realized on scheduled milestones in a predictive planning*" (Silvius-Zuchi & Silvius, 2024b). This form of hybrid can be found in the proposed "*Agile-Stage-Gate*" methodology (Sommer et al., 2015; Conforto & Amaral, 2018; Žužek et al., 2020). And although this typology provides a first understanding of different forms of hybrid, the variety of hybrid needs further development in order to provide effective guidance on the applicability of the different forms.

### *2.4. Scenarios fitting a hybrid approach*

A hybrid approach should be tailored to the situational circumstances of a specific project (Lalmi et al., 2021). The criteria model of Silvius-Zuchi & Silvius (2024b), as shown in Figure 1, can be used to identify different situational scenarios, in which a hybrid approach would be most fitting. For example, for a specific project, the product-related and team related criteria might score more on the right side of the model, indicating that an adaptive approach would fit, but the organization related criteria might score mostly on the left side, indicating that a predictive approach would fit. So, this would be a situation where an adaptive approach would fit, however, combined with practices that improve the predictability of the project for the governing organization. A typical 'integrated' hybrid approach (Timinger, 2017).

By combining different left-right scores for the three categories of criteria, in total eight hypothetical situational scenarios can be identified. Two of them, all three categories left and all three categories right, would call for a fully predictive, respectively a fully adaptive approach, but six scenarios would show a mixed left-right score on the categories of criteria, and therefore call for a hybrid approach. Figure 2 illustrates these six scenarios on the model of Silvius-Zuchi & Silvius (2024b).

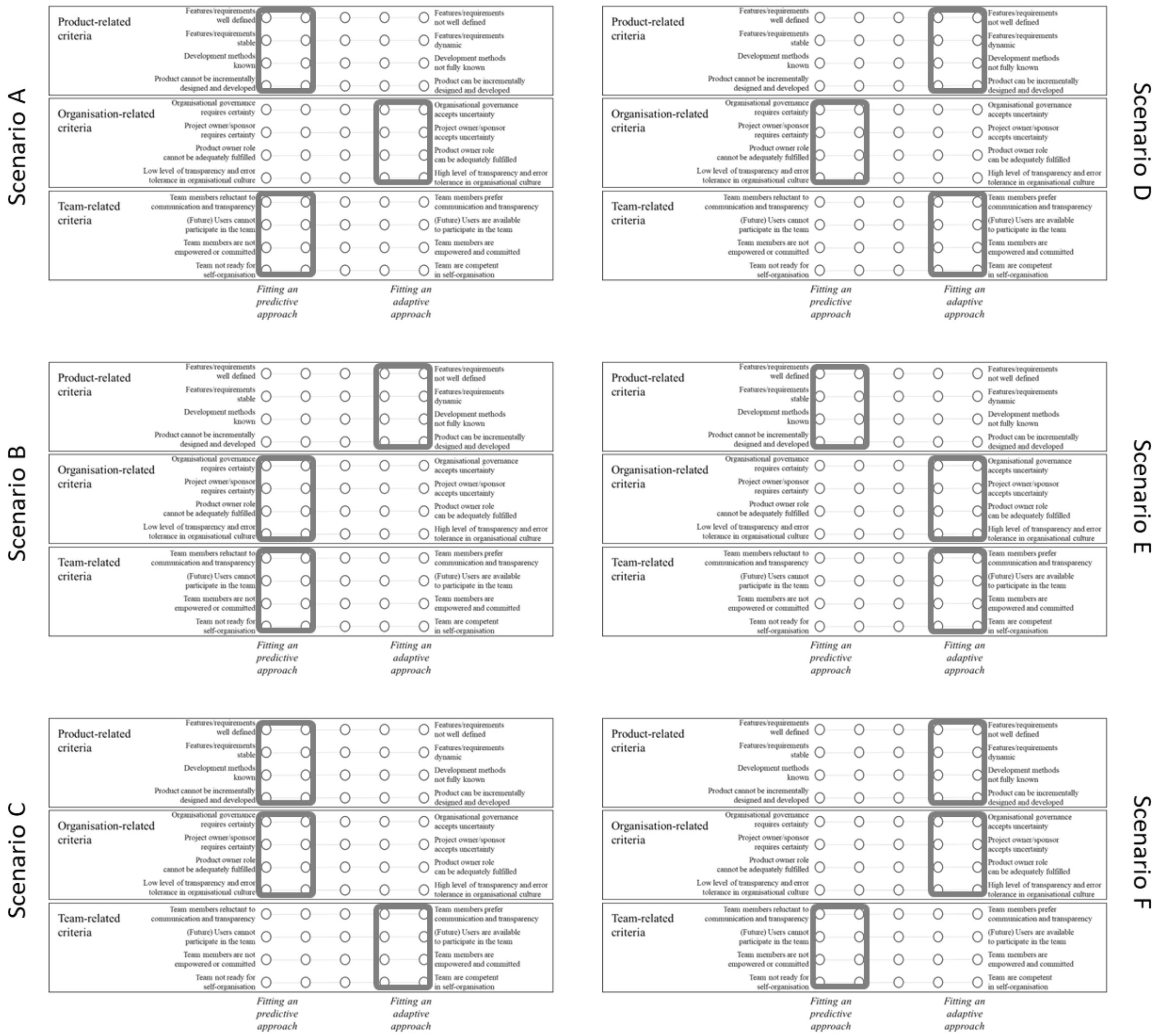


Fig. 2. Overview of hybrid situational scenarios, based on the applicability assessment of the predictive and adaptive approaches.

Figure 2 shows six possible situational scenarios of mixed left-right scores, with the highlighted blocks indicating the predominant scoring pattern of each scenario, indicating situations in which a hybrid approach would be fitting. These scenarios are described below.

- Scenario A can be characterized as a situation in which the organization and the project owner are quite flexible and open in their governance of the project, although the deliverable of the project can be well-defined, with stable requirements. The team also needs a ‘predictive’ specification of deliverables, timelines and budgets, with clear tasks for each team member. In this scenario, there seems to be a disconnect in the acceptance of transparency and uncertainty between the operational level of project team and future users, and the management and governance levels in the organization. At first sight, it can be thought that this situation simply calls for a predictive approach in which the project owner demonstrates a certain level of acceptance of issues and exceptions that may occur during the project. However, the disconnect in the acceptance of transparency and uncertainty between the different level in the organization, may be a symptom of a larger issue within the organization, which may hinder its ability to change (Bennebroek Gravenhorst et al., 2003).

- Scenario B can be characterized as a situation in which the organization, project owner and the team require clarity and a well-defined 'predictive' specification of deliverables, timelines and budgets. This predictability, however, gets challenged by a dynamic or unclear set of requirements for the deliverable. This type of project would call for a hybrid approach with design elements and practices that make a predictive approach more adaptive.
- In scenario C, there appears to be a desire within the team to work in a more adaptive way, although the organization and the product do not really call for it. And although this scenario seems unlikely as it appears not really feasible to work adaptive, the scenario is not uncommon form, as the change to an adaptive way of working was frequently 'pushed' or driven by the development team and their organizations. Sometimes this happened transparently, but often also 'stealth', meaning unknown to the organization, project owner and future users. A challenge arising in this situation is logically the predictability of project outputs, timelines and budgets, and how to 'manage' the development team that thrives with self-organization. This scenario would call for a hybrid approach with practices that make an adaptive development more predictive.
- Scenario D can be characterized as a situation that basically would call for an adaptive approach, however, the organization and the project owner require more predictability of deliverables, timelines and budget. It is this scenario that was described in the example earlier. This scenario would call for an integrated hybrid approach, in which the development team works in an adaptive way, while committing itself to delivering defined (partial) results on scheduled milestones in a predictive planning (Silvius-Zuchi & Silvius, 2024). It might be argued that in this way of working some of the advantages of the adaptive approach get lost, but that is probably inevitable. The internal and external governance of organizations requires a certain level of predictability of project budgets, outputs and outcomes in order to evaluate investments and managerial decisions.
- In scenario E, the organization and the team appear to be well suited for an adaptive approach, although the deliverable of the project is well-defined, with stable requirements. In this situation, the approach can be designed as adaptive, although it can be questioned whether the essence of the adaptive approach can be effectively utilized. The essence of the adaptive approach is the reduction of the need for a complete and detailed description of the user's requirements at the start of the development process, as requirements are only detailed and defined 'just-in-time' during the development process. When the deliverable is completely defined upfront, one of the most important benefits of the adaptive approach falls away. In this scenario it may therefore be recommendable to investigate why the deliverable is already defined completely at the start of the development process, and whether a more adaptive approach to the requirements of the deliverable would still be beneficial.
- In scenario F, the dynamic or unclear set of requirements for the deliverable of the project would call for an adaptive approach, and the organization and project owner also accept the uncertainty that comes with this. However, in this situation, the team and the future users are not ready for an adaptive approach, and need a clear specification of deliverables, timelines and budgets, with clear tasks for each team member. This situation can appear for example when the user organization has gone through a painstaking negotiation process in order to come up with a defined set of requirements for the deliverable, and does not accept that this discussion is reopened. In a situation like this, it will also be quite hard to fulfil the product owner role. Another example of this scenario is when the members in the project team do not feel comfortable with the transparent, communicative and self-organizing way of working, that is characteristic in the adaptive approach. A situation like this may therefore call for a more intense coaching and facilitation of the development team, for them to work in a more adaptive way.

The six situational scenarios identified above require different hybrid practices in order to fit the characteristics of the project's product, team and governing organization. Some scenarios call for design choices that make predictive projects more adaptive, whereas other scenarios call for choices that make adaptive practices more predictive. The specification, per scenario, of these design choices, is the core contribution the study reported in this paper aims to make. By combining the six identified situational scenarios above with the design elements of an approach, a typology of hybrid approaches can be developed. For the design choices, the earlier identified set of design elements (Table 2) will be used. The specification of the design choices per scenario, and the resulting hybrid typology, will be reported in the results section of the paper.

## 3. Methodology

### *3.1. Research approach*

Considering the practical orientation of the aim of the study, we approached the study from a pragmatic perspective. The outputs of our study should therefore be judged on their "fit" with their purpose (Von Glasersfeld, 2001), and not on their "truth" or "true explanation" as is common in studies using a positivist paradigm (Avenier, 2010). In this we followed the scholars, for example Cannella and Paetzold (1994), that pointed out the inadequacy of the positivist paradigm as a model for organization research.

The study aims to help bridge the "*relevance gap*" between researchers and practitioners (Aram & Salipante 2003; Tranfield & Starkey 1998), by developing a typology of design choices that can be used to solve the practical issue of how to apply predictive practices in adaptively approached projects, and vice versa. This aim positions the study as a design science research (DSR) study. DSR can be seen as a paradigm "*rather than a discrete research methodology*" (Baskerville et al., 2009). In DSR, methodological rigor is balanced with the demands of practical utility (Wieringa, 2010). From a design science perspective, the main purpose of academic management research is to develop practical knowledge to support organizational problem solving in the field (Saunders et al. 2015). That support can be direct, instrumental or more indirect, giving general enlightenment on the type of problem at hand.

Pragmatism and organizational design science developed in parallel as alternative models of science well suited to the study of organizational phenomena (Avenier, 2010). In the pragmatic research paradigm, acceptable knowledge can be derived from either or both observable phenomena and subjective meanings (Saunders et al. 2015). The study at hand used insights from DSR to develop practically usable project management artefacts.

### *3.2. Research process*

The research process followed a structured process that was loosely based on Brown (2008). The following steps were performed:

- Based on the literature on the criteria for selecting a fitting approach for a project, six scenarios were identified, in which a 'pure' predictive or a 'pure' adaptive approach would not be adequate, and therefore a hybrid approach needs to be designed. This step was reported in the background section.
- Based on the literature on what characterizes the predictive and adaptive approaches to project management, six design elements were identified that operationalize the design choices in a hybrid approach. This step was also reported in the background section.
- Based upon the results of the two steps described above, Figure 3 depicts the design logic of the study.
- Per type of hybrid scenario, a fitting hybrid project management design was developed, based on the practices of the predictive and adaptive approaches, as shown in Table 2. This part of the study is reported in the results section of the paper.

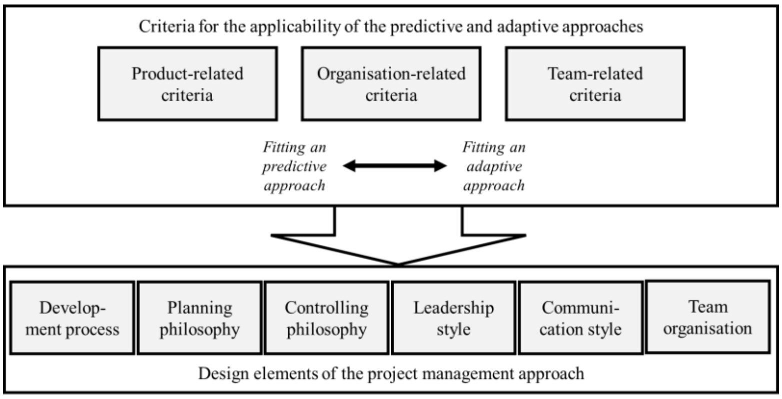


Fig. 3. Overview of the design logic of the study

### *3.3. Design logic*

The 'design logic' of coupling the design choices with the six different situational scenarios was based on their expected 'fit' with the situational characteristics of the specific scenario. This 'fit' was assessed based on the characteristics of the design choice in the predictive and adaptive approaches found in literature and described in section 2.1.

The concept of 'fit' comes from contingency theory, and can be defined as the consistency or coherence between different attributes of the organization, together forming its configuration (based on Drazin & Van de Ven, 1985; Klaas, 2004). The design of a 'fit' synthesis requires the identification of relevant frameworks (Carroll et al., 2013) as described above, the identification of potential relationships between the different elements of components of the frameworks, and the analysis of the degree of 'fit' of these relationships, based on an understandable logic. In the study presented here, the assumed 'fit' of the relationships between project management design choices and types of hybrid represent the views and expectations of the research team which, given the pragmatic approach of the study, is considered acceptable. Critical in the approach of the study is that the artefacts are designed according to an imperative or prescriptive logic. In this, as stated earlier, methodological rigor is balanced with the demands of practical utility (Wieringa 2010).

### *3.4. Testing the model*

A final step in DSR is preferably the testing of the designed artefact (Brown, 2008). In the study reported in this paper, this testing is planned for further research. This provides a limitation to the study, however, the developed model still fulfills the aim of the study and represents a contribution to the much-needed understanding of hybrid project management.

## 4. Results

### *4.1. Situational hybrid approaches*

In this section, six different hybrid project management approaches will be designed, based on their expected fit with the six situational scenarios discussed earlier. The six hybrid approaches are summarized in Table 3, and discussed below.

- Hybrid approach A 'Tolerant predictive', is basically a predictive approach, but with a tolerant governance by the project owner and the organization. This removes the need for a detailed upfront planning of budget and schedule, although the activities still need to be detailed for internal control purposes. It is advisable to be transparent about the tolerances that the governance allows for.

- Hybrid approach B 'Flexible predictive', is primarily predictive, but with more flexibility for changes of the requirements of the deliverable. This is realized by splitting up the development process in multiple development cycles. Not to the degree that the adaptive approach does that, but sufficient to handle at least some of the changes in an adaptive manner. A role of product owner is established for organizing (changes) in user requirements.
  A condition for this 'Flexible predictive' hybrid approach, is that the user organization can make a distinction between minimal and optional requirements of the deliverable.

- Hybrid approach C, 'Predictable adaptive', is a frequently found hybrid approach, in which the team works primarily adaptive, but within a governance structure that is predictive. This would require that the team, although working adaptively, still commits to a final deliverable. In this approach, there is upfront decision making on budget and duration, which can only work if there is a certain level of flexibility with regards to the requirements of the deliverable. Also in this approach it is advisable to establish a 'Product Owner' role for organizing user communication on requirements, although it may not be possible to have the user organization fulfil this role. The 'stealth' mode of this approach, in which the project owner and the user organization may not be aware that the project team works adaptively, should be avoided.

- Hybrid approach D, 'Integrated hybrid', is an approach that fits the frequently heard desire to make adaptive projects more predictable in terms of deliverables, timelines and costs. In this approach, the process is organized as an adaptive approach, with frequent short development cycles, but milestones are defined that correspond with a predicted delivery of (partial) deliverables. The milestones should not be scheduled after a single development cycle, but after a reasonable number of short cycles. Probably 6 – 20. Also in this approach it is a condition that the user organization can make a distinction between minimal and optional requirements of the partial deliverables. The controlling in this approach is primarily product oriented, but with an additional orientation on realizing the agreed milestones. Also in this approach, a product owner role is established.

- Hybrid approach E, 'Adaptive light', is an approach that is primarily adaptive. However, one key-characteristic of the adaptive approach, defining and prioritizing requirements 'just-in-time' at the start of each development cycle, is in this hybrid approach not really functional, as the requirements for the deliverable can be defined in total upfront. Nevertheless, it is still advisable to establish a product owner role also in this approach, as this is an indispensable role in the adaptive approach.

- Hybrid approach F, 'Facilitated adaptive', is primarily an adaptive approach, but with additional elements to facilitate and coach the team in this approach. These elements include a planning of activities, in addition to a product backlog. And as the team is not ready for the self-organization that is characteristic for the adaptive approach, the leadership style within the project should be adapted with situational choice of transactional and servant leadership styles. In this approach, also more emphasis is on a coaching role for supporting and facilitating the team.

The six hybrid approaches described above can be seen as a situational typology of hybrid approaches. With this typology, the different forms and interpretations of the hybrid approach can be characterized, thereby contributing to the further development of the understanding of hybrid project management.

Table 3. Overview of the six hybrid approach designs, fitting the six identified situational scenarios

More Predictive ⟷ More Adaptive

| Design element | **Hybrid approach A fitting scenario A**<br>*'Tolerant predictive'* | **Hybrid approach B fitting scenario B**<br>*'Flexible predictive'* | **Hybrid approach C fitting scenario C**<br>*'Predictable adaptive'* | **Hybrid approach D fitting scenario D**<br>*'Integrated hybrid'* | **Hybrid approach E fitting scenario E**<br>*'Adaptive light'* | **Hybrid approach F fitting scenario F**<br>*'Facilitated adaptive'* |
|---|---|---|---|---|---|---|
| Development approach | Primarily predictive: One, or a few, development cycles<br>Define the total set of requirements at the start of each development cycle<br>Inspection of quality primarily at the end of the cycles, but also continuous if possible | Primarily predictive, but splitting up the development process in multiple development cycles<br>Define the requirements at the start of each development cycle<br>Inspection of quality primarily at the end of the cycles, but also continuous if possible | Primarily adaptive, splitting up the development process in short frequent development cycles, but with a defined final deliverable<br>Defining and prioritizing requirements at the start of the development process, but with the option to change requirements as late as possible in the process<br>Inspection of quality primarily at the end of the development process, but also continuous if possible | Primarily adaptive, splitting up the development process in short frequent development cycles, but with defined periodical milestones that are (partial) deliverables or releases<br>Define the requirements for the partial deliverable at the start of each development cycle<br>Inspection of quality primarily at the end of the cycles, but also continuous if possible | Adaptive, with many short development cycles<br>Defining and prioritizing requirements at the start of the development process, but with the option to change requirements as late as possible in the process<br>Continuous inspections of quality | Adaptive, with many short development cycles<br>Defining and prioritizing requirements at the start of each development cycle<br>Continuous inspections of quality |
| Planning & Controlling philosophy | Product oriented upfront planning, distinguishing between minimal and optional requirements, with detailing of activities<br>High level upfront estimation of budget and duration<br>Clarity about tolerances<br>Product oriented controlling<br>Include social controlling to facilitate team development and learning | Distinguish between minimal and optional requirements<br>Implement a flexible change management process<br>Include product oriented control variables in planning & control, next to time and budget<br>Include social controlling to facilitate team development and learning | Distinguish between minimal and optional requirements<br>Upfront decision making on budget and duration, with some flexibility in the requirements of the deliverable<br>Include product oriented control variables in planning & control, next to time and budget<br>Frequent reflection moments to facilitate team development and learning | Distinguish between minimal and optional requirements for partial deliverable milestones<br>Product oriented upfront planning, with a product backlog per partial deliverable milestone<br>Upfront decision making on budget and duration, with some flexibility in the requirements of the deliverable<br>Product and milestone oriented controlling | Product oriented upfront planning, distinguishing between minimal and optional requirements<br>High level estimation of budget and duration<br>Rolling decision making on budget and duration<br>Product oriented controlling<br>Frequent reflection moments to facilitate team development and learning | Product oriented upfront planning, distinguishing between minimal and optional requirements, with detailing of activities<br>High level estimation of budget and duration<br>Rolling decision making on budget and duration<br>Product oriented controlling<br>Frequent social controlling to facilitate team development and learning |
| Leadership style | Situational choice of transactional and servant styles | Situational choice of transactional and servant styles | Transformational, Participative and Servant | Transformational, Participative and Servant | Transformational, Participative and Servant | Situational choice of transactional and servant styles |
| Communication style | Conversation based<br>High level of transparency within the team and between the team and future users | Document user requirements and changes<br>High level of transparency within the team and between the team and future users | Conversation based<br>High level of transparency within the team and between the team and future users | Conversation based<br>High level of transparency within the team and between the team and future users | Conversation based<br>High level of transparency within the team and between the team and future users | As much as possible conversation based, but with documented user requirements<br>Considerable level of transparency within the team and between the team and future users |
| Team organization | Functional-hierarchical<br>Operational level decision making on requirements<br>Support of the team depending on leadership style | Functional-hierarchical<br>Strategic level decision making on requirements<br>Establish a 'Product Owner' role for organizing (changes) in user requirements | High level of self-organization, but with commitment to the timeline of the deliverable<br>Strategic level decision making on requirements and changes<br>Establish an internal 'Product Owner' role for organizing user communication | High level of self-organization, but with commitment to milestones that are partial deliverables<br>Operational level decision making on requirements and changes<br>Establish a 'Product Owner' role for organizing user requirements | High level of self-organization<br>Strategic level decision making on requirements<br>Establish a 'Product Owner' role for organizing user requirements | Functional-hierarchical<br>Operational level decision making on requirements<br>Establish a coaching role for supporting and facilitating the team |

### *4.2. Discussion*

The hybrid approach to project management is still an emerging field of study, with many unknowns. Hybrid is not a single methodology (Lalmi et al., 2021), but stands for an spectrum of approaches that all combine elements and practices from the predictive and adaptive approaches. The study reported in this paper, identified six different hybrid approaches, in Table 3 ordered from 'more predictive' (left in the table) to 'more adaptive' (right in the table). As such it can be concluded that the hybrid approaches C 'Predictable adaptive', and D 'Integrated hybrid' are the two approaches in which there is most integration of the predictive and adaptive approaches. Whereas in the approaches A and B are predominantly predictive in nature, and the approaches E and F predominantly adaptive. This typology provides a framework for positioning hybrid methodologies, such as the ones proposed by Sommer et al. (2015), Adelakun et al. (2017), Conforto & Amaral (2018), Žužek et al. (2020), Lalmi et al. (2021) and Azenha et al. (2021). As such it contributes to the theoretical understanding of hybrid project management. In fact, the framework reveals a gap in the literature. Most published hybrid methodologies, such as the ones referenced above, focus on designing a methodology that contributes to the predictability of adaptive, or agile, projects. In this context, for example Adelakun et al. (2017) talk about "*Agile with discipline*". These hybrid methodologies can be categorized as the approaches C 'Predictable adaptive', or D 'Integrated hybrid'. The literature, however, lacks developed methodologies that are more to the sides of the typology of Table 3.

The contribution that the typology of six different hybrid approaches makes, is strengthened by its fit with six situational scenarios. This contingency approach provides a further contribution to the literature and understanding of hybrid. In their literature review on hybrid project management, Reiff & Schlegel (2022) concluded that while the various proposed hybrid methodologies "*are interesting and have advanced the discussion in the field, a general procedure to develop a hybrid approach or criteria to guide a meaningful combination of traditional and agile elements are still missing*" (Reiff & Schlegel, 2022: 59). They recommend that future research should "*develop procedures, criteria or frameworks that help organizations to select appropriate methods and design bespoke hybrid methodologies that are tailored to the specific project and organizational context*". The study reported in this paper can be seen as replying to this call. And as the study was designed to provide practical guidance, its contribution goes beyond a further developed conceptual understanding of the hybrid approach. The frameworks of situational scenarios and corresponding fitting hybrid design choices, provide practical guidance to project managers that need to design the approach for a specific project and want to base that design on the situational circumstances of the project.

The contingency approach proposed in this paper aims to enable the project owner and manager to design a fitting hybrid approach for a specific project. As selecting the right approach may influence the success of a project (Chin & Spowage, 2010; Špundak, 2014), understanding the fit of the project management approach with the situational circumstances is important for project managers and project owners/sponsors. Earlier studies found a positive impact of the hybrid approach on project success (Gemino et al., 2021), however, these studies did not distinguish different types of hybrid approaches. Further empirical research is needed to investigate this, and we hope that the typology developed in this study will provide a basis for this.

Another point of discussion is the question whether the predictive and adaptive approaches can be effectively combined in a single approach, given the differences in their design and philosophy. Zasa et al. (2021) raise this question and for good reasons. As the discussion of the two approaches in section 2.1 shows, some differences between the approached, such as the philosophy of planning and controlling a project are so different that they should be considered mutually exclusive. In the design of a hybrid approach it is therefore important to evaluate the overall consistency of the design choices in a hybrid approach. In the hybrid approaches presented in Table 3, this overall consistency has been considered. A further direction of research may also be the appearance of the different hybrid approaches, as not all of them seems to have a clear rationale. For example approach C 'Predictable adaptive' may seem irrational, as the project team should logically align its approach with the characteristics of the product and the organization. However, the research team has come across various cases that matched C, leaving the project manager with the issue of designing an effective approach for this scenario.

## 5. Conclusion

The study reported in this paper set out to answer the question Which design choices in a hybrid approach fit the situational characteristics of the project and its environment? Based on the criteria for assessing the fit of an predictive or an adaptive approach found in literature, the study identified six situational scenarios in which a combination of predictive and adaptive, a hybrid approach, would be most fitting. The descriptions of the approaches found in literature also provided the basis for the identification of a set of design elements, through which an approach can be designed.

When matching the design elements to the situational circumstances of the six identified scenarios, the study applied a pragmatism approach combined with a design science process to develop a typology of six hybrid approaches: 'Flexible predictive'; ''Tolerant predictive'; 'Predictable adaptive'; 'Adaptive light'; 'Integrated hybrid' and 'Facilitated adaptive'. These six hybrid approaches, that fit the six identified situational scenarios. provide a contingency perspective on the hybrid approach in project management, thereby contributing to the further development and understanding of this approach.

The study bears implications of project management professionals, business organizations and academia. Project management professionals should understand that the hybrid approach is not a single defined way of working, but a spectrum of design choices, that together form an approach. Professionals should also develop their competence in assessing a project’s situational circumstances and designing an approach that fits these circumstances. And although this may provide an infinite number of hybrid approaches, the typology of six approaches developed in this study, provides a supporting framework for the design decisions these professionals need to make. By analyzing the characteristics of the project’s intended deliverable, governing environment and team, the project management professional can now characterize the situational scenario and use the typology of hybrid approaches to find suggestions for fitting design choices.

To organizations a hybrid approach may sound like an attractive ‘best of both worlds’ approach in project management, however, they should understand that the characteristics of the predictive and adaptive approaches are as such that it may not always be possible to combine both approaches effectively. A consistent hybrid approach therefore requires a thorough consideration of several design choices, that should fit the characteristics of the project and the organization. Hybrid is not a defined methodology, but an approach that comes in a spectrum of variations. For many projects a complete integration of the predictive and adaptive approaches may not be required, and it may suffice to implement practices that make a predictive project a bit more adaptive, or an adaptive project a bit more predictive. The six hybrid approaches developed in this study provide guidance for this.

For the academic community, the typology of six hybrid approaches provides several opportunities for further research, as are mentioned in the discussion section. With regards to project management curricula in higher education, the framework presented in this paper can be used to provide more insight in the variety of approaches that fall under the label hybrid.

A limitation of the study is that the ‘fit’ between the different hybrid approaches and their situational scenarios, is not empirically tested. As discussed in section 3.4, the study presented in this paper did not include a test or evaluation phase. This would provide an opportunity for follow-up research in the future, although such a study would need to develop a procedure in order to establish the ‘fit’ of an approach. Mere empirical existence of a certain scenario would not provide sufficient proof for its fit with the situational circumstances.

## Declarations

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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International Journal of Information Systems and Project Management (IJISPM)
2026, 14(1), e140104, DOI: 10.12821/ijispm140104

RESEARCH ARTICLE

# Outsourced ERP system implementation success: The effects of client and vendor competences and their moderating roles

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**Abstract**
Previous research has overlooked how individual competence interacts with circumstances that could potentially affect the success of outsourced system implementation. This research leverages person-environment fit and expectation-disconfirmation theories to investigate how client and vendor competences, as external factors and moderators, along with partnership quality and task-technology fit, affect the performance and satisfaction in outsourced ERP system implementations. Data were collected via a survey of 414 ERP users from 12 companies and analyzed using PLS-SEM and slope analysis. The findings reveal that client and vendor competences shape task-technology fit and partnership quality, affecting performance and client satisfaction. Notably, task-technology fit does not always improve performance for highly competent clients, and satisfaction may decline when vendors are perceived as highly competent, raising client expectations. A slight misalignment between tasks and technologies may even benefit highly skilled users. Furthermore, client satisfaction with ERP outsourcing is influenced by both performance outcomes and perceptions of vendor competence. This study provides practical guidance to enhance the success of outsourced system implementations.

**Keywords**
system implementation; outsourcing; ERP; competence; partnership; task-technology fit; performance impacts; satisfaction.

Received: 7 October 2024 | Accepted: 23 June 2025

## 1. Introduction

In the realm of effective outsourcing for system implementation, ensuring alignment between the competences of clients and vendors is crucial, even though clients and vendors have different roles in the outsourced system implementation process (Karimi-Alaghehband & Rivard, 2020; Navarro-Paule et al., 2023). The capabilities and behaviors of individuals, which arise from their competences, significantly influence outcomes over time. Rather than simply reacting to their surroundings, individuals actively choose the environments they engage with (Kandler et al., 2024). The person-environment fit theory posits that people are inclined to choose situations that resonate with their preferences, leading to better performance in suitable settings (Lee et al., 2021; Kristof, 1996). Individuals may prefer certain work environments that match their competence for effective task execution. Competence encompasses the knowledge, skills, and attitudes or dispositions that enable individuals to navigate various situations (Rosamilha et al., 2023; Frezza et al., 2018). Those with higher levels of competence can actively shape their circumstances, resulting in different outcomes. Research suggests that more competent individuals often take on more complex tasks (Frezza et al., 2018; Kohn & Schooler, 1978). High achievers, leveraging their competencies, often seek and excel in challenging environments that demand substantial accomplishments (Parbat, 2024; Chatman, 1989). This highlights that the competence levels of clients and vendors in a given situation may affect the success of outsourced system implementation.

Achieving success in outsourced system implementation also relies on the quality of partnerships that bring together the efforts of involved parties to pool resources and achieve mutual goals that would not be easily achieved individually (Ee et. al., 2013; Lee & Kim, 1999). Prior studies have also employed the task-technology fit perspective as a critical determinant of success in system implementation (Valaei et al., 2019; D'Ambra et al., 2013). The alignment between tasks and technology influences users' utilization and performance outcomes (Howard & Hair, 2023). However, the relationship between partnership quality and task-technology fit remains ambiguous. Moreover, prior research has attempted to incorporate the direct effects of individual characteristics in explaining users' evaluation of the fit between task and technology characteristics (Valaei et al., 2019; Wells et al., 2003) but has overlooked the moderating role of individual characteristics, particularly individual competences, in the relationship between task-technology fit and performance outcomes.

Furthermore, the expectation-disconfirmation theory suggests that individuals establish initial expectations, and any deviation from this reference point impacts their satisfaction levels (Zhang et al., 2021; Oliver, 1980). In the outsourced system implementation, clients tend to set higher performance expectations when they perceive vendors as highly competent and vice versa, affecting their satisfaction levels (Harmon-Jones & Mills, 2019). Hence, varying levels of vendor competence may impact clients' satisfaction levels differently. Ultimately, the diverse levels of individual competences, either client or vendor competence, have the potential to interact with circumstances shaping performance outcomes and satisfaction, thereby playing a crucial role in the success of outsourced system implementation. Nonetheless, prior research has often overlooked the role of individual competence as a moderator in the success of outsourced system implementation.

To address these research gaps, this study aims to explore the relationships between client competence, vendor competence, partnership quality, and task-technology fit as well as their implications for the success of outsourced system implementation. Specifically, this study delves into the moderating roles of client and vendor competences in explaining the outsourced system implementation success associated with performance impacts and client satisfaction. The primary focus of this study is on the implementation success of enterprise resourcing planning (ERP) systems, given the prevalent outsourcing of ERP components by organizations and the challenges encountered in their implementation with service providers (Ahmed et al., 2024). This study presents a new research framework that enhances the understanding of outsourced system implementation success by highlighting the impacts of individual competences, as exogenous and moderating factors, on outsourced system implementation success grounded in the person-environment fit and expectation-disconfirmation theories. In addition, practical guidelines for enhancing user performance and satisfaction are outlined to increase the potential success of outsourced system implementation.

The subsequent section presents theoretical perspectives underpinning the research model, followed by the development of hypotheses, research methodology, and analysis findings. Theoretical and practical implications are then explored before concluding with a discussion of study limitations and suggestions for future research.

## 2. Theoretical perspectives underpinning the study

To provide a structured understanding of the diverse theoretical foundations relevant to outsourced ERP implementation success, this study organizes the theories into three distinct sections. These sections align with the conceptual stages of the outsourcing process. The first section focuses on the competence perspective, which explains the fundamental rationale behind outsourcing decisions. The second section addresses ERP outsourcing and success measures, presenting commonly used indicators for evaluating the success of ERP outsourcing initiatives. The last section encompasses theories that examine the relational, technical, and psychological factors influencing success during the implementation phase, including the partnership perspective, task-technology fit, person-environment fit, and expectation-disconfirmation theory.

### *2.1. Competence perspective*

The term competence is ambiguous and defined differently in various contexts (Rosamilha et al., 2023; Winterton & Turnbow, 2020). Scholars often portray competence as a blend of interconnected knowledge, skills, attitudes, and behavior that impact individual performance and can be enhanced through training and development (Hefley & Bottion, 2021; Parbat, 2024). Numerous scholars cite dispositions to encompass attitudinal and behavioral components of competency. Disposition can be defined as attitudes, values, commitments, and professional ethics that influence behaviors and enable the transformation of knowledge and skills into action, allowing individuals to act decisively in specific situations whenever opportunity is present (Rosamilha et al., 2023; Frezza et al., 2018; Weinert, 2001). Unlike knowledge and skills, dispositions are usually considered as habits of mind or natural inclinations to respond to certain situations in certain ways (Frezza et al., 2018). From the competence perspective in the context of outsourcing, competences can be described as the knowledge, skills, and dispositions that client and vendor firms must acquire to effectively implement a system. Achieving success in the outsourced system implementation needs alignment between client and vendor competences, even though clients and vendors have different roles in the system implementation (Karimi-Alaghehband & Rivard, 2020). In addition, levels of client and vendor competences have various effects on the success of outsourced system implementation (Navarro-Paule et al., 2023). Being competent isn't just about knowing things (Knowledge) or being able to do them (skills), it also involves the right disposition (attitudes/behavior) (Weinert, 2001). All these aspects work together to make someone truly competent (Frezza et al., 2018; Rosamilha et al., 2023). Therefore, the competence variable is defined as a formative higher-order construct consisting of two lower-order constructs including knowledge & skills, and disposition.

Client knowledge & skills relate to the clients' understanding and ability to utilize outsourced services and meet their task requirements (Bassellier et al., 2003). During the outsourced system implementation phase, client knowledge & skills regarding ERP applications, organizational operations, and system management are essential for vendors to effectively develop the outsourced ERP system and provide services aligned with the client's needs (Bardhan et al., 2009). Client disposition reflects clients' willingness to engage an outsourcing provider by providing and supporting necessary resources during the system implementation process (Karim et al., 2007; McIvor et al., 2011). This disposition assists vendors in identifying the client's ERP system requirements and capabilities, as well as providing the essential information and resources for a successful system implementation.

Vendor knowledge & skills relate to a vendor's specialized knowledge and expertise in handling and supporting a client's services, technical standards, and best practices (Lacity et al., 2016). Research indicates that vendor knowledge & skills significantly benefit client firms, particularly for those with higher IT intensity in their operations (Chang & Gurbaxani, 2012). Vendors with extensive knowledge and expertise in implementing similar outsourced systems and familiarity with a client's business operations can streamline the system implementation process and enhance their ability to meet the client's requirements effectively. Vendor disposition indicates the vendor's readiness to deliver services as promised and assist clients as needed (Kaipia & Tanskanen, 2003). This disposition compels vendors to deliver services as agreed upon and promptly respond to clients' requirements, enhancing client satisfaction with the outsourced system.

### *2.2. ERP outsourcing and success measures*

In the past decade, rapid industrial transformation and the global impact of COVID-19 have significantly disrupted the economy and business operations, prompting organizations to reassess the balance between internal and external resources (Oshri et al., 2025). In this context, Enterprise Resource Planning (ERP) systems have garnered substantial interest for their capacity to streamline operations, enhance decision-making, and foster innovation across business functions. ERP implementation typically follows a structured and resource-intensive approach—encompassing system planning, customization, integration, testing, and user training—often requiring a high level of technical and managerial expertise (Yarfi et al., 2025). To address these demands, many organizations have adopted selective outsourcing of specific IT components within ERP implementations—such as accounting, logistics, and sales/marketing—as a strategic means to improve cost-efficiency, mitigate implementation risks, access specialized knowledge, and enhance operational flexibility (Hossain et al., 2025). This targeted outsourcing approach allows organizations to retain control over core functions while leveraging external expertise where it adds the most value (Pires & Varajão, 2025). This dual evolution—transforming both business operations through ERP systems and IT service delivery through selective outsourcing—has significantly reshaped organizational practices. Nevertheless, despite the maturity of ERP technologies, implementations remain complex and susceptible to delays, budget overruns, and failure (Rajapakse et al., 2023). Accordingly, this study focuses on the selective outsourcing of IT services in ERP system implementation, with the aim of exploring its role in achieving successful ERP outcomes.

Since outsourcing clients frequently lack or do not share criteria for evaluating the success or failure of their outsourcing agreements (Gonzalez et al., 2008), it can be difficult to define and measure success in outsourcing. Nonetheless, a number of academics suggest evaluating the success of outsourcing by looking at overall satisfaction with the outsourced implementation and perceived benefits (Han et al., 2008; Paudel & Kumar, 2021; Karimi-Alaghehband & Rivard, 2020). Satisfaction is a reliable measure of outsourcing success because it incorporates a holistic evaluation of the costs and benefits involved and serves as a valid metric, unlike other specific measures such as cost control and access to emerging technologies that may not be applicable in all situations (Paudel & Kumar, 2021; Gonzalez et al., 2008). Perceived benefits refer to the client's assessment of the advantages that outsourcing provides. These benefits not only underpin the reasons for engaging in an outsourcing contract but also represent the client's expectations of performance impacts. Perceived benefits, thus, measure the extent to which clients' expectations have been met (Kim & Chung, 2003).

In addition, vendors' and clients' perspectives about the success of outsourcing may differ. Vendors usually evaluate the success of implementation based on system outputs, such as the number of products or services delivered according to the service contract (Hoseini & Nikabadi, 2021). In contrast, clients who outsource their services take into account not only these outputs but also outcomes like user satisfaction, service quality, and the overall impact on the business (Iriarte & Bayona, 2020). Accordingly, this research evaluates the success of outsourced system implementation based on two key outcomes: client satisfaction and performance impacts. Client satisfaction reflects a client's perceptions of information systems meeting expectations (Klepper, 1995), while performance impact signifies the impact of computer systems and services on a client's work quality and job performance (Olson & Dover, 1979).

### *2.3. Theories influencing success during outsourcing implementation*

*Partnership perspective*: Partnerships that combine the efforts of concerned parties to pool resources and accomplish mutual goals are essential to the success of outsourcing system implementation (Ee et. al., 2013; Lee & Kim, 1999). Several key assumptions underpin the concept of partnerships (Winterton & Turnbow, 2020). Partnership is the potential for synergy, where the combined effort of concerned parties yields results exceeding the capabilities of individual party. Partnerships also encompass both the collaborative development and execution of a strategy, project, or operation, although partner involvement may vary across different stages. In the context of IT outsourcing, partnership refers to the collaborative efforts of all parties involved in pooling IT resources to reach shared goals that would be difficult to achieve alone. This collaboration is vital for the success of outsourced system implementation (Hancox & Hackney, 2000; Lee & Kim, 1999). Various partnership models have been proposed in previous literature. Klepper (1995) reviewed marketing literature to develop an IS partnership model. Lee and Kim (1999) integrated social exchange theory and political power perspective into their partnership model. Partnership quality refers to the extent of the relationship between two parties in finding the probability of continuous interchange between those parties in the future. It also encompasses the level of collaboration between vendor and client teams during system implementation. Research indicates that factors such as information exchange, communication, and collaborative participation positively affect the intensity of the relationship with the outsourcing vendor, thereby enhancing partnership quality (Bardhan et al., 2009; Lee & Kim, 1999). The partnership quality is a key determinant of outsourcing success and requires active participation, clear communication, open information sharing, and top management support (Lee & Kim, 1999; Ee et. al., 2013). While partnership quality is essential for successful outsourcing, it alone may not dictate the success of outsourced system implementation.

*Task-technology fit perspective:* Prior studies have employed the task-technology fit perspective to identify the success of outsourced system implementation (Valaei et al., 2019; D'Ambra et al., 2013). Task-technology fit (TTF) theory argues that the effectiveness of technology in enhancing individual performance is higher when the capabilities of the technology align with the tasks required by users (Howard & Hair, 2023; Goodhue & Thompson, 1995). The degree of alignment between individual characteristics and technology characteristics plays a crucial role in determining the levels of task-technology fit (Valaei et al., 2019; Wells et al., 2003). Moreover, the compatibility between a task's characteristics and various technologies can result in varying levels of task-technology fit (Wells et al., 2003). The common task-technology fit factor captures individuals' perceptions of task-technology fit (Goodhue & Thompson, 1995). An expanded TTF model, referred to as the technology-to-performance chain model, not only highlights the effects of utilization and user attitude on individual performance but also clarifies how technology enhances performance and its overall impact (Howard & Hair, 2023). Unlike earlier studies that focused on user assessments of task-technology fit by treating individual characteristics as either independent variables or moderators, this study explores how individual characteristics, specifically client competence, moderate the relationship between task-technology fit and performance impacts.

*Person-environment fit theory:* Person-environment fit theory investigates the interaction between an individual's characteristics and their environment, and the appropriateness of this fit can impact the person's motivation and behavior (Kristof, 1996). Many scholars have utilized person-environment fit to elucidate the relationships between individual competencies and task requirements (Kandler et al., 2024; Holland, 1997). Persons tend to select situations that match their preferences and perform better in environments that suit them. Individuals seek to achieve fit because they tend to prefer consistency, have a need for belonging, and aim to reduce uncertainty. The concept of person-environment fit has been expanded to encompass various perspectives, including person–job fit, person–team fit, and person-organization fit. In the work context, optimal job performance and satisfaction are achieved when persons select tasks or environments that align with their competences (Holland, 1997). Persons will introduce new situational requirements when employing technologies to fulfill their tasks (Lee et al., 2021). Moreover, persons with intellectual flexibility typically excel in demanding environments that require significant achievement levels (Chatman, 1989). Therefore, it is important to ensure that users with distinguished capabilities can use technology to perform evolving demand tasks, leading to high job performance. However, the relationship between a person's capability and the environment in which technology fits well with the users' tasks has not been empirically investigated in the context of outsourced system implementation.

*Expectation-disconfirmation theory:* Expectation-disconfirmation theory is a cognitive model seeking to explain consumer satisfaction from the difference between pre-usage expectations and the post-usage perceptions of a product or service (Zhang et al., 2021; Oliver, 1980). Individuals establish reference points for their anticipated experience. Any divergence from these established expectations can negatively impact their satisfaction levels. The disconfirmation concept is aligned with cognitive dissonance theory, which suggests that individuals face a psychological dilemma when their actions do not align with their beliefs and cognitions (Harmon-Jones & Mills, 2019). Disconfirmation can be categorized into three types. Negative disconfirmation occurs when actual performance falls short of an individual's expectations, leading to dissatisfaction. Positive disconfirmation occurs when actual performance surpasses expectations, resulting in satisfaction. Finally, simple confirmation takes place when actual performance equals expectations (Carraher-Wolverton & Hirschheim, 2023). In an IT outsourcing context, a client's perceptions of a vendor's capabilities are typically rooted in indirect sources, such as industry analyses, conferences, publications, and vendor assertions disseminated through impersonal or mass communication platforms. This information has the potential to lead clients to develop possibly inflated expectations regarding IT outsourcing partnerships. Clients who possess prior exposure to outsourced services tend to formulate more pragmatic expectations (Carraher-Wolverton & Hirschheim, 2023); nevertheless, in the absence of direct involvement with the service, expectations may be shaped by other sources like previous users, media reports, or promotional campaigns (Carraher-Wolverton, 2024). The realistic vendor's performance expectation plays a crucial role in determining client satisfaction upon the successful execution of outsourcing agreements.

## 3. Hypothesis development and research model

The extent to which technology can execute a user's tasks depends on how well individual capabilities, task requirements, and technological functionalities align (Goodhue & Thompson, 1995). Individuals will apply their competencies from prior knowledge and experience to effectively utilize technology for completing demanding tasks (Zhang et al., 2024). Clients possessing high competencies in specific ERP system applications and organizational operations can utilize these competencies to enhance task performance on the system. Therefore, client competence plays a crucial role in shaping the relationship between tasks and technology.

*H1: Client competence has a positive impact on task-technology fit.*

The ERP system comprises diverse functions and applications that necessitate clients' resources and active participation during the implementation phase (Ee et al., 2013). Client competence, regarding their understanding and skills related to organizational processes, required system functions, and their willingness to engage in resource sharing with vendors, is vital for successful implementation (Jain & Khurana, 2016). Consequently, client competence fosters effective collaboration and communication with vendors, thereby enhancing partnership quality (Al-Azad et al., 2022).

*H2: Client competence has a positive impact on partnership quality.*

Task-technology fit is dependent on how well individual capabilities, task requirements, and technology functionalities align (Goodhue & Thompson, 1995). Competent vendors can utilize their competencies, which include knowledge of ERP system functions and applications, to configure the system according to clients' needs. They can also promptly solve client system usage issues by aligning the system with client tasks. Vendor competence shapes the alignment between technology and tasks.

*H3: Vendor competence has a positive impact on task-technology fit.*

Vendors with high competence can offer valuable guidance and efficiently resolve client issues based on their experience in implementing various outsourcing systems. Clients place trust in highly competent vendors with specialized knowledge and experience in system implementation. Highly competent vendors can leverage their expertise to execute tasks effectively and collaborate efficiently with clients, enhancing partnership quality (Lee & Kim, 1999; Levina & Ross, 2003).

Moreover, vendors' readiness to deliver services, through their competence, can demonstrate a high level of commitment by providing timely support and delivering services within agreed timelines, thereby fostering strong collaboration and trust between both parties (Levina & Ross, 2003).

*H4: Vendor competence has a positive impact on partnership quality.*

Throughout the outsourced system implementation, the client's and vendor's project teams must collaborate to establish a system that aligns with the client's requirements. Achieving synergy between both parties' efforts, rather than individual efforts, is crucial for the technology-task fit. This synergy signifies partnership quality resulting from effective collaboration and communication between the two parties (Lee & Kim, 1999; Teo & Bhattacherjee, 2014). Therefore, partnership quality plays a significant role in facilitating the alignment between technology and tasks during the outsourced system implementation process.

*H5: Partnership quality has a positive impact on task-technology fit.*

Technology that has the potential to assist users in their tasks can significantly influence the performance of users (Goodhue & Thompson, 1995). The efficiency and effectiveness of users can be enhanced, leading to improved productivity and quality of work, if the system is appropriately configured for the users' tasks. The fit between the system and the tasks being performed allows for a more substantial impact on user performance (Howard & Hair, 2023). Conversely, the misfit between tasks and the system causes operational difficulties and lowers user performance.

*H6: Task-technology fit has a positive impact on performance impacts.*

Partnership quality plays a crucial role in fostering collaboration between vendor and client teams to ensure the system's performance meets user requirements and fulfills the vendor's service agreement (Lee & Kim, 1999). Moreover, partnership quality significantly relates to a lower risk of system malfunctions and improves project performance (Klepper, 1995). In essence, partnership quality is essential to guarantee the influence of the system on user performance.

*H7: Partnership quality has a positive impact on performance impacts.*

The level of performance meeting an individual's expectations contributes to their satisfaction (Wang & Zhou, 2022). Job performance involves achieving crucial job values (e.g., task activities and accomplishments) and influences job satisfaction (Locke, 1970). Clients will be satisfied with the outsourced system if they can use the system to improve their work quality and productivity. Clients will find satisfaction in the outsourced system if they can utilize it to enhance the quality and productivity of their work (Olson & Dover, 1979). Accordingly, the more benefits clients perceive from the outsourced system, the higher their satisfaction with the system will be.

*H8: Performance impact has a positive impact on client satisfaction.*

The person-environment fit theory suggests that people tend to select situations that align with their preferences and perform better in environments that suit them (Kristof, 1996). People are inclined towards work settings based on their competencies to carry out their tasks effectively. For instance, people with high levels of intellectual flexibility tend to favor the complexity of their work tasks (Kohn & Schooler, 1978). High achievers, leveraging their competencies, typically thrive in challenging environments that demand high levels of accomplishment (Chatman, 1989). Additionally, when people utilize technology to complete tasks, they may introduce new demands into their work situations (Lee et al., 2021). Accordingly, an excessive fit between tasks and technology could lead to ineffective behavior by limiting users' adaptability in changing technology usage to meet the evolving demands of their tasks, particularly for those with high competence. This exacerbates the misfit between persons and their work environment, thereby diminishing client performance arising from the fit between task and technology.

*H9: Client competence moderates the impact of task-technology fit on user performance, where high client competence dampens the relationship between task-technology fit and performance impacts.*

Drawing from the expectation-disconfirmation theory, disconfirmation arises when there is a gap between what users expect and what actually happens (Oliver, 1980). This disconfirmation influences levels of user satisfaction (Carraher-Wolverton, 2024). When users perceive that actual performance exceeds their expectations (positive disconfirmation), their satisfaction increases. Conversely, if users' expectations surpass actual performance (negative disconfirmation), satisfaction decreases. Clients assess vendor competence based on prior experience with the outsourced service or information provided by vendors and advertisers, which helps shape their expectations of vendor competence. When clients perceive vendors as highly competent, they tend to set higher performance expectations, increasing the likelihood of encountering negative disconfirmation and decreasing satisfaction.

*H10: Vendor competence moderates the effect of performance impact on user satisfaction, where high vendor competence dampens the relationship between performance impacts and client satisfaction.*

Diverse theories and perspectives contribute to the development of these hypotheses, which in turn shape the research model in Figure 1.

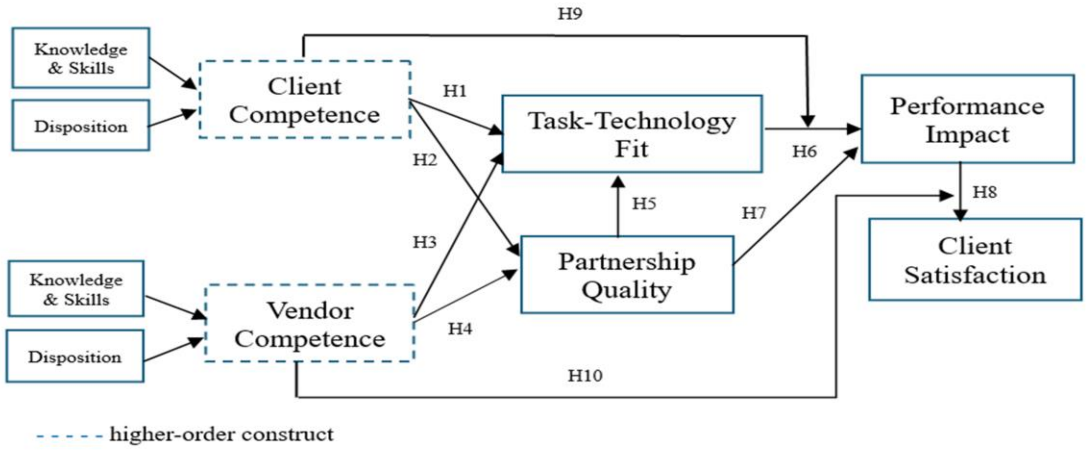


Fig. 1. Research model

## 4. Methodology

### *4.1. Sampling and data collection*

This study employed a survey methodology to collect data through a structured questionnaire. The instrument comprised measurement items adapted from established and validated constructs in prior scholarly works, as detailed in Appendix A. Respondents were requested to indicate their level of agreement with a series of statements using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Data collection was conducted using purposive sampling, targeting 12 companies across four major industries—food and beverage, services, glass, and plastics. These companies all engage in some form of outsourced ERP services—such as accounting, marketing, procurement, or production—with service providers based in Thailand. To ensure both linguistic accuracy and conceptual consistency in the translated questionnaire, a double translation technique was employed, involving an initial translation from English to Thai followed by a reverse translation from Thai back to English. The questionnaire was distributed to individuals designated by their respective companies to participate in the study. These companies, all clients of a firm affiliated with one of the authors, were contacted through authorized company representatives, primarily senior executives, who were invited to facilitate participation. These representatives subsequently disseminated the questionnaires to appropriate ERP users within their companies, including senior managers, department managers, and end users. A total of 445 completed questionnaires were returned within one month. Following a screening process to remove incomplete responses and statistical outliers, 414 usable questionnaires, representing a response efficiency rate of 93%, were retained for further analysis. This sample size exceeds the commonly recommended minimum of 200 cases and meets the guideline of being at least 20 times the number of parameters in the research model, thereby supporting the application of structural equation modeling (SEM) as the primary analytical technique. The demographic characteristics of the respondents, presented in Table 1, indicate that 52.2% were female, with 42.3% aged between 25 and 30 years. The majority of respondents were employed in logistics and production functions, and 40.6% reported having between one and three years of experience with ERP systems.

Table 1. Respondents' profile

| **Demographic Data** | | **Frequency** | **Percent** |
|---|---|---|---|
| Gender | Male | 198 | 47.8 |
| | Female | 216 | 52.2 |
| Age | 20-24 years | 15 | 3.6 |
| | 25-30 years | 175 | 42.3 |
| | 31-35 years | 122 | 29.5 |
| | 36-40 years | 46 | 11.1 |
| | >40 years | 56 | 13.5 |
| Position | Senior manager | 12 | 2.9 |
| | Department manager | 51 | 12.3 |
| | Department staff | 351 | 84.8 |
| Department | Accounting | 82 | 19.8 |
| | Logistic | 156 | 37.7 |
| | Sales/Marketing | 68 | 16.4 |
| | Production/Purchasing | 108 | 26.1 |
| Industry | Glass | 101 | 24.4 |
| | Plastic | 105 | 25.4 |
| | Food/Beverage | 106 | 25.6 |
| | Service | 102 | 24.6 |
| Work Experience | 1-3 years | 145 | 35.0 |
| | >3-5 years | 109 | 26.3 |
| | >5-10 years | 84 | 20.3 |
| | >10-20 years | 40 | 9.7 |
| | >20 years | 36 | 8.7 |
| ERP Experience | 1-3 years | 168 | 40.6 |
| | >3-5 years | 123 | 29.7 |
| | >5-10 years | 75 | 18.1 |
| | >10 years | 48 | 11.6 |

### *4.2. Data analysis*

This study utilized a variance-based structural equation modeling technique, specifically the partial least squares method (PLS-SEM), to investigate the research model. This method is helpful because it can assess the quality of formative and reflective constructs, examine the moderating effects, and simultaneously test the various cause-and-effect paths (Hair et al., 2014). The PLS-SEM approach consists of two assessment models: the measurement model and the structural model. The measurement model assesses the relationships between the latent constructs and their respective indicators, while the structural model examines the relationships among the latent constructs. The PLS-SEM analysis was conducted using SmartPLS software version 4.0 (Ringle et al., 2024).

To address potential threats to the validity of research findings related to using the same method for collecting data across multiple variables, this study employed Harman's single-factor test to assess common method bias (CMB). This test checks if a single factor accounts for a large portion of the covariance, which would indicate the presence of common method variance. The results showed that a single factor only explained 29.523% of the variance, which is below the 50% threshold. This suggests that common method bias is not a significant issue in this study (Howard et al., 2024). In other words, the common method variance does not appear to distort the results or predictions of the study.

### *4.3. Measurement model assessment*

The measurement model was assessed to confirm both construct reliability and validity. As shown in Table 2, the indicator loadings for all constructs exceeded the threshold value of 0.708, indicating that the construct explains over 50 percent of the indicator's variance (Hair et al., 2014). Reliability was assessed through two measures: Cronbach's Alpha and Composite Reliability (CR). Both measures surpassed the commonly accepted threshold of 0.70, suggesting that the indicators within each construct consistently measure the underlying concept (Hair et al., 2014). Convergent validity, which signifies the extent to which the indicators portray their intended latent construct, was assessed using Average Variance Extracted (AVE). Table 2 indicates that an AVE value exceeding 0.50 for each construct demonstrates that a greater proportion of the variance in the indicators is explained by the underlying construct, rather than by measurement error (Fornell & Larcker, 1981).

Table 2: Loadings, reliability, and convergent validity

| Constructs | Items | Loadings | Cronbach's Alpha | Composite reliability (CR) | Average variance extracted (AVE) |
|---|---|---|---|---|---|
| Client knowledge & skill (CKS) | CKS1 | 0.931 | | | |
| | CKS2 | 0.879 | 0.846 | 0.907 | 0.766 |
| | CKS3 | 0.811 | | | |
| Client disposition (CDP) | CDP1 | 0.910 | | | |
| | CDP2 | 0.922 | 0.913 | 0.945 | 0.851 |
| | CDP3 | 0.934 | | | |
| Vendor knowledge & skill (VKS) | VKS1 | 0.760 | | | |
| | VKS2 | 0.822 | 0.704 | 0.833 | 0.624 |
| | VKS3 | 0.786 | | | |
| Vendor disposition (VDP) | VDP1 | 0.913 | | | |
| | VDP2 | 0.926 | 0.904 | 0.940 | 0.839 |
| | VDP3 | 0.909 | | | |
| Task-technology fit (TTF) | TTF1 | 0.725 | | | |
| | TTF2 | 0.887 | 0.747 | 0.855 | 0.665 |
| | TTF3 | 0.827 | | | |
| Partnership quality (PNQ) | PNQ1 | 0.851 | | | |
| | PNQ2 | 0.792 | | | |
| | PNQ3 | 0.737 | 0.891 | 0.919 | 0.694 |
| | PNQ4 | 0.903 | | | |
| | PNQ5 | 0.873 | | | |
| Performance impacts (PMI) | PMI1 | 0.767 | | | |
| | PMI2 | 0.880 | | | |
| | PMI3 | 0.726 | 0.884 | 0.913 | 0.678 |
| | PMI4 | 0.893 | | | |
| | PMI5 | 0.838 | | | |
| Client satisfaction (CSF) | CSF1 | 0.855 | | | |
| | CSF2 | 0.809 | 0.850 | 0.899 | 0.690 |
| | CSF3 | 0.879 | | | |
| | CSF4 | 0.779 | | | |

2026, 14(1), e140104, DOI: 10.12821/ijispm140104

Discriminant validity ensures that the constructs being measured are distinct from each other. Two validation assessments were carried out: Fornell-Larcker criterion and heterotrait-monotrait ratio (HTMT). The Fornell-Larcker assessment, presented in Table 3, compares the square root of AVE for each construct with its correlations with other constructs. The diagonal elements, representing the square root of the AVE, consistently held higher values than the corresponding values in their respective rows and columns. This pattern indicates that each construct shares more variance with its own indicators than with those of other constructs (Fornell & Larcker, 1981). Additionally, HTMT values for all constructs were below the recommended threshold of 0.85, providing further evidence of discriminant validity. By satisfying these criteria for both reliability and validity, the measurement model establishes a solid foundation for the subsequent analysis of hypothesized relationships among the constructs in the structural model (Hair et al., 2014; Sarstedt et al., 2019).

Table 3: Discriminant validity

| Const. | Fornell-Larcker | | | | | | | | Heterotrait-monotrait ratio (HTMT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CKS | CDP | VKS | VDP | TTF | PNQ | PMI | CSF | CKS | CDP | VKS | VDP | TTF | PNQ | PMI | CSF |
| CKS | 0.87 | | | | | | | | | | | | | | | |
| CDP | 0.45 | 0.92 | | | | | | | 0.50 | | | | | | | |
| VKS | 0.23 | 0.26 | 0.79 | | | | | | 0.28 | 0.30 | | | | | | |
| VDP | 0.40 | 0.32 | 0.61 | 0.92 | | | | | 0.46 | 0.34 | 0.73 | | | | | |
| TTF | 0.22 | 0.35 | 0.46 | 0.37 | 0.82 | | | | 0.27 | 0.41 | 0.62 | 0.43 | | | | |
| PNQ | 0.32 | 0.30 | 0.40 | 0.47 | 0.50 | 0.83 | | | 0.35 | 0.31 | 0.47 | 0.51 | 0.57 | | | |
| PMI | 0.29 | 0.24 | 0.22 | 0.28 | 0.29 | 0.31 | 0.82 | | 0.34 | 0.26 | 0.28 | 0.31 | 0.37 | 0.35 | | |
| CSF | 0.14 | 0.22 | 0.23 | 0.20 | 0.20 | 0.25 | 0.48 | 0.83 | 0.20 | 0.25 | 0.30 | 0.22 | 0.25 | 0.30 | 0.51 | |

### *4.3.1 Validating higher-order construct*

Improperly classifying constructs as formative or reflective can lead to inaccurate assessments of construct quality (Sarstedt et al., 2019). Competence is a multifaceted concept encompassing an individual's knowledge, skills, and disposition (Weinert, 2001). Without the disposition component, knowledge and skills alone are insufficient for effective competence (Frezza et al., 2018). Because these various components contribute independently to the overall concept of competence, it is most appropriately modeled as a formative higher-order construct. Consequently, client competence (CCPT) is further divided into two lower-order constructs including client knowledge-skills (CKS) and client disposition (CDP). Similarly, vendor competence (VCPT) comprises two lower-order constructs including vendor knowledge-skills (VKS) and vendor disposition (VDP).

To ensure the validity of the higher-order construct representing competence, multicollinearity using the variance inflation factor (VIF) was initially assessed. VIF values below 5 generally indicate no multicollinearity issues (Hair et al., 2014). As illustrated in Table 4, the VIF values ranged from 1.249 to 1.609, confirming no multicollinearity concerns. Subsequently, the statistical significance and relevance of the weights assigned to each lower-order construct were examined. All outer weights were found significant ($p<0.001$), and outer loadings were significant for each indicator (lower-order construct) forming the higher-order constructs ($p< 0.001$). These findings together support the validity of the higher-order competence construct (Sarstedt et al., 2019).

Table 4: Higher-order construct validation

| HOCs | LOCs | VIF | Outer Weights | T Statistics | P Values | Outer Loadings | P Values |
|---|---|---|---|---|---|---|---|
| CCPT | CKS | 1.249 | 0.533 | 5.113 | <0.001 | 0.820 | <0.001 |
| | CDP | 1.249 | 0.641 | 6.706 | <0.001 | 0.879 | <0.001 |
| VCPT | VKS | 1.609 | 0.595 | 5.966 | <0.001 | 0.913 | <0.001 |
| | VDP | 1.609 | 0.518 | 5.006 | <0.001 | 0.883 | <0.001 |

Note: HOCs: Higher Order Constructs, LOCs: Lower Order Constructs, CCPT: Client Competence, VCPT: Vendor Competence

### *4.4. Structural model assessment*

To assess the structural model, the proposed hypotheses are subjected to examination, with the outcomes demonstrating support for all hypotheses at varying levels of significance (Table 5). Following this, the explanatory power of the model is appraised, revealing $R^2$ values ranging from 0.191 to 0.331 for the endogenous variables. Notably, $R^2$ values of 0.75, 0.50, and 0.25 are deemed substantial, moderate, and weak, respectively (Sarstedt et al., 2019). Consequently, the $R^2$ values pertaining to the endogenous constructs can be described as weak explanatory power. The assessment of predictive relevance is conducted through the utilization of the $Q^2$ value. The $Q^2$ values range from 0.074 to 0.257 for the endogenous constructs, surpassing 0 and thereby indicating that the model outperforms the most native benchmark (Hair et al., 2014).

Table 5: Structural model assessment results

| Relationships | Beta Coefficient$^+$ | Beta Coefficient | T statistics | $f^2$ | P values | Results |
|---|---|---|---|---|---|---|
| CCPT -> TTF | 0.132 | 0.119 | 2.390 | 0.017 | 0.008** | H1: supported |
| CCPT -> PNQ | 0.201 | 0.206 | 4.540 | 0.049 (s) | <0.001*** | H2: supported |
| VCPT -> TTF | 0.246 | 0.252 | 4.524 | 0.068 (s) | <0.001*** | H3: supported |
| VCPT -> PNQ | 0.409 | 0.404 | 6.905 | 0.190 (m) | <0.001*** | H4: supported |
| PNQ -> TTF | 0.340 | 0.342 | 6.825 | 0.127 (s) | <0.001*** | H5: supported |
| TTF -> PMI | 0.172 | 0.109 | 1.801 | 0.010 | 0.036* | H6: supported |
| PNQ -> PMI | 0.225 | 0.161 | 2.885 | 0.022 (s) | 0.002** | H7: supported |
| PMI -> CSF | 0.487 | 0.430 | 11.434 | 0.220 (m) | <0.001*** | H8: supported |
| CCPT x TTF -> PMI | | -0.166 | 4.057 | 0.046 (s) | <0.001*** | H9: supported |
| VCPT x PMI -> CSF | | -0.104 | 2.651 | 0.014 | 0.004** | H10: supported |
| **Endogenous Constructs** | $R^{2+}$ | $R^2$ | $\Delta R^2$ | $Q^2$ | | |
| TTF | 0.331 | 0.331 | 0.000 | 0.231 | | |
| PNQ | 0.271 | 0.271 | 0.000 | 0.257 | | |
| PMI | 0.119 | 0.191 | 0.072 | 0.142 | | |
| CSF | 0.237 | 0.257 | 0.020 | 0.074 | | |

Note. $^+$ The noninteraction model ; $f^2$ effect size: (s)=small, (m)=medium ; Relationship significance at * $p < 0.05$, ** $p < .01$, *** $p<.001$

### *4.5. Moderation analysis*

The study assessed the moderating role of client competence (CCPT) on the relationship between task-technology fit (TTF) and performance impacts (PMI), as well as the moderating role of vendor competence (VCPT) on the relationship between performance impact (PMI) and client satisfaction (CSF). The significance of the moderating effect was analyzed. Figure 2 indicates the negative and significant moderating effect of CCPT on the relationship between TTF and PMI ($\beta$=-0.166, $p<0.001$), supporting H9. The results also highlighted the negative and significant moderating effect of VCPT on the relationship between PMI and CSF ($\beta$=-0.104, $p<0.01$), supporting H10.

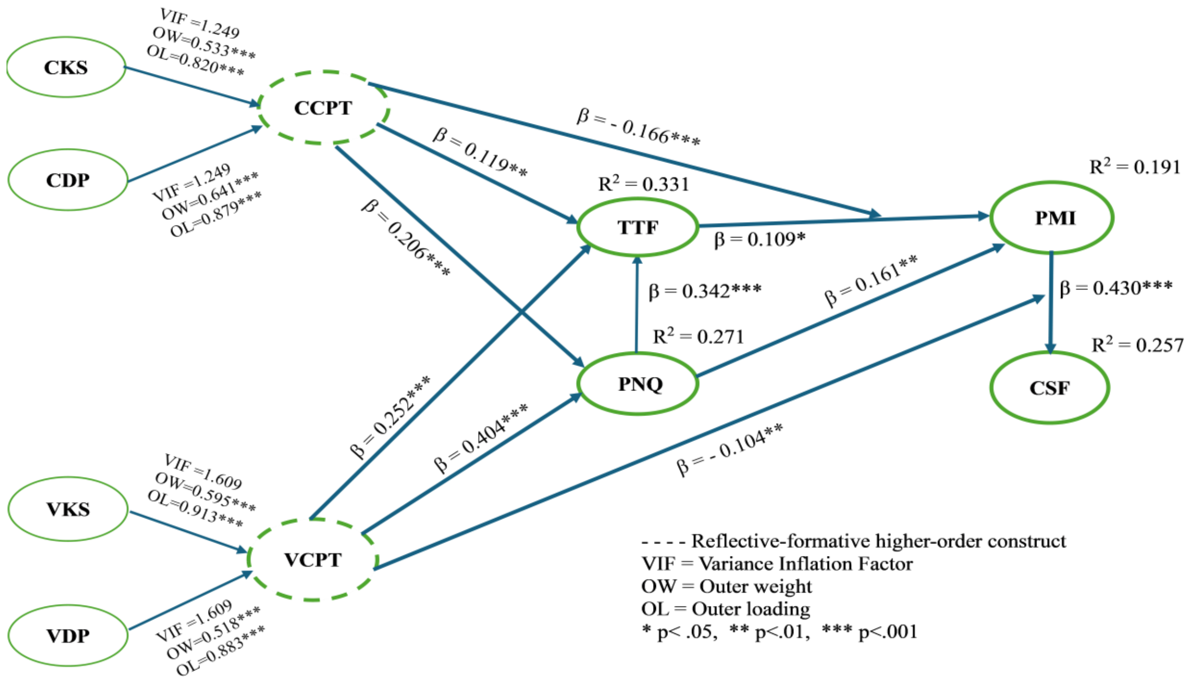


Fig. 2. Research model results

To ascertain the extent of the interaction effects (CCPT*TTF and VCPT*PMI), this study conducted a comparative analysis of the outcomes derived from two distinct models (i.e., non-interaction and interaction models) with respect to their discrepancy in $R^2$. The noninteraction model accounts for 11.9% of the variance in performance impacts (PMI) and 23.7% of the variance in client satisfaction (CSF), whereas the interaction model explained 19.1 % of the variance in PMI and 25.7 % of the variance in CSF. The overall interaction effect size ($f^2$) for the CCPT*TTF and VCPT*PMI were 0.046 and 0.014, respectively (Table 5). According to Cohen's proposition, values of 0.02, 0.15, and 0.35 are indicative of small, medium, and large effect sizes, respectively (Cohen, 1988). This indicates that the interaction effect size of CCPT*TTF makes a small contribution to explaining PMI, while the interaction effect size of VCPT*PMI in explaining CSF is minimal. Cohen (1988) contended that a low effect size ($f^2$) does not inevitably signify an insignificant effect. Hence, the interaction model demonstrates significantly greater explanatory capabilities ($R^2$) compared to the primary non-interaction model. These outcomes validate the interaction effects of CCPT*TTF and VCPT*PMI, thereby providing strong support for H9 and H10.

Furthermore, the slope analysis is utilized to gain a deeper understanding of the moderating effects (Figure 3). As shown in Figure 3a, the trend line reversed for CCPT reveals that at high CCPT (+1 SD), TTF negatively influences PMI. In accordance with the person-environment fit viewpoint, excessively high levels of task-technology fit may restrict the adaptability of competent individuals, typically excel in demanding environments that require significant achievement levels, to improve their performance in a new environment (using technology to perform evolving demands). As shown in Figure 3b, the trend line for high VCPT demonstrates a markedly reduced steepness, indicating that at high VCPT, the influence of PMI on CSF has a significantly less impact compared to low VCPT. Drawing on the expectation-disconfirmation theory, clients tend to establish heightened performance expectations when perceiving vendors as highly competent, elevating the chances of encountering negative disconfirmation (expectation exceeds actual performance) and consequently diminishing their satisfaction with the system performance provided by the vendors.

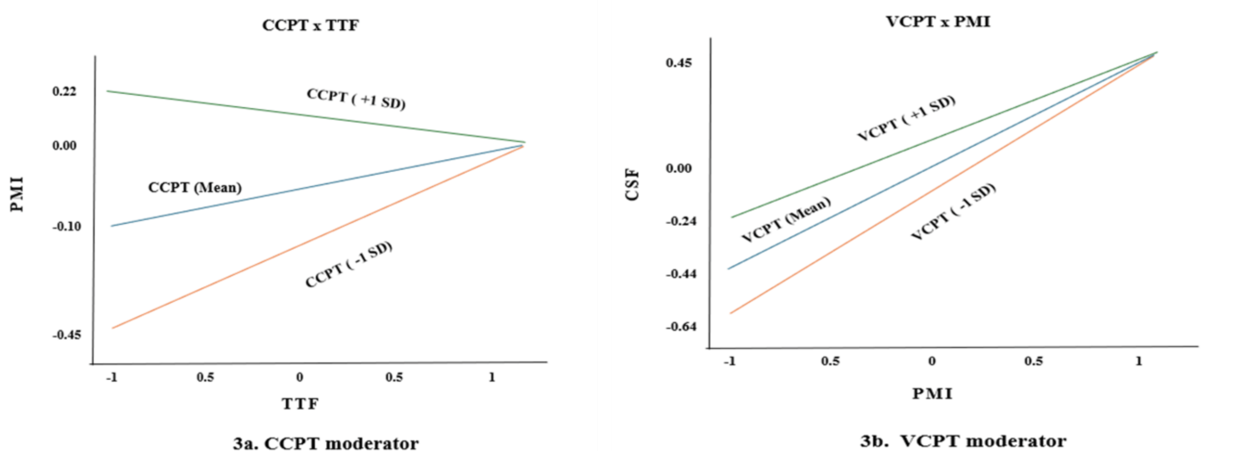


Fig. 3. Slope analysis results of the moderators' impacts

## 5. Discussion and implications

The findings highlight the importance of both client and vendor competences in the successful implementation of outsourced ERP systems, primarily through their influence on task-technology fit and partnership quality. As shown in Table 5, client competence has a significant positive effect on task-technology fit (β=0.119, p<0.01), supporting H1. This suggests that competent clients leverage their prior knowledge and experience to effectively utilize ERP technologies in executing complex tasks. This finding aligns with the Task-Technology Fit theory, which posits that individual characteristics—in this case, competences—shape the degree to which technology supports task performance (Goodhue & Thompson, 1995). Additionally, client competence significantly influences partnership quality (β=0.206, p<0.001), thus supporting H2. This result indicates that higher levels of client competence facilitate more effective collaboration with vendors, ultimately enhancing the quality of the partnership (Al-Azad et al., 2022). Similarly, vendor competence demonstrates a significant effect on task-technology fit (β=0.252, p<0.001), supporting H3. This finding highlights that competent vendors apply their expertise, particularly their knowledge of ERP systems and applications, to tailor solutions that meet client-specific requirements. Furthermore, vendor competence significantly contributes to partnership quality (β=0.404, p<0.001), providing support for H4. This outcome confirms that vendor competence enhances collaboration and builds trust, both of which are critical elements of high-quality partnerships (Levina & Ross, 2003).

The findings presented in Table 5 demonstrate that partnership quality significantly enhances task-technology fit (β=0.342, p<0.001), providing support for H5. This suggests that alongside individual characteristics influencing task-technology fit (Goodhue & Thompson, 1995), characteristics of the partnership also influence this fit. A strong task-technology fit, in turn, leads to better performance impacts. This is evidenced by the positive effect of task-technology fit on performance impacts (β=0.109, p<0.05), supporting H6. Moreover, partnership quality significantly improves user performance (β=0.161, p<0.01), providing support for H7 and reinforcing the notion that effective partnerships contribute to smoother system operations and better project outcomes (Klepper, 1995). The findings also reveal that performance impacts positively influence client satisfaction (β=0.430, p<0.001), supporting H8, and highlighting that clients are more satisfied when the outsourced ERP system effectively enhances work performance (Olson & Dover, 1979).

Importantly, the findings presented in Figure 3a provide an insight into the relationship between task-technology fit and performance impact. Contrary to the core premise of task-technology fit theory, which posits that a higher degree of alignment between task requirements and technological capabilities leads to improved user performance (Goodhue & Thompson, 1995), the results indicate that this relationship does not hold uniformly across all contexts. Specifically, the data reveal that when client competence is high, the positive influence of task-technology fit on performance outcomes is significantly reduced. This suggests that highly competent clients may have more advanced, dynamic, or evolving performance expectations that are not fully met by systems perceived as adequately fitting for their tasks. In such cases, even a well-aligned system may fail to deliver perceived performance gains, possibly due to the misalignment between the system's capabilities and the sophisticated demands of expert users. This interaction effect provides empirical support for H9, indicating that the effectiveness of task-technology fit in driving performance impact is contingent on the level of client competence. In addition, Figure 3b reveals a similar moderating effect in the relationship between performance impact and client satisfaction. Although performance improvements generally lead to higher satisfaction, this effect is weakened when clients hold elevated expectations from highly competent vendors. That is, when vendor competence is perceived to be high, clients may expect exceptional performance outcomes. As a result, even positive performance impacts may be viewed as insufficient, thereby diminishing their influence on overall satisfaction levels. This moderating effect supports H10 and highlights the importance of managing client expectations in high-competence vendor relationships. Together, these results underscore the conditional nature of ERP outsourcing success factors, particularly where user and vendor competences are high.

### *5.1. Theoretical implications*

This study sheds light on three important implications for theories. Firstly, it addresses the gap in existing literature on the success of outsourced system implementation by incorporating the person-environment fit and expectation-disconfirmation theories to explore the moderating roles of individual competences on outsourced system implementation success. Particularly, it delves into the moderating impacts of individual competences by exploring the interaction effects between client competence and task-technology fit on performance impacts as well as the interaction effects between vendor competence and performance impacts on client satisfaction.

Secondly, this study contributes to a deeper understanding of task-technology fit theory by challenging the idea that a perfect fit between tasks and technology leads to better performance. The results reveal that a fit between tasks and technology might have unintended consequences for highly competent users (Figure 3a). This study suggests that a certain degree of misfit between tasks and technologies might be advantageous for users with highly competent in enhancing task performance and meeting evolved performance requirements. According to the person-environment fit perspective, people tend to select situations that match their preferences, and those with greater capabilities typically excel in challenging settings that demand high levels of achievement (Chatman, 1989). Excessive levels of task-technology fit could lead to ineffective behaviors by limiting adaptability to changing the technological approach for executing non-routine tasks and fulfilling escalating task demands of highly competent users. This phenomenon can exacerbate the person-environment misfit, ultimately diminishing the initially anticipated performance gains associated with a strong task-technology fit.

Thirdly, this study enhances understanding of factors contributing to information systems success by revealing that the improvement in user performance does not consistently heighten user satisfaction in the context of outsourcing system implementation. Specifically, the increase in user satisfaction resulting from performance impacts is lessened when clients hold high performance-expectations from highly competent vendors (Figure 3b). In line with the expectation-disconfirmation theory, individuals establish an initial set of expectations, and any deviation from this initial benchmark influences their satisfaction levels. Due to the fact that individuals' expectations are shaped by their perceptions and experiences, they tend to raise performance expectations from vendors with high competence. This could potentially lead to negative disconfirmation, where actual performance falls short of users' expectations, thereby lowering their satisfaction levels.

### *5.2. Practical implications*

This study highlights two important implications for practices. Firstly, clients need to ensure that the outsourced ERP system they utilize possesses the essential scalability and flexibility required to effectively adapt to changing environments and the diverse needs of users with highly competent. This study demonstrates that a misalignment between persons and their environment arises when clients with highly competent engage with outsourced systems that closely fit the tasks they need to execute, potentially leading to a reduction in client performance (Figure 3a). Hence, it is recommended that clients consider the scalability features of their outsourced systems to handle increasing workloads, transactions, and data volumes while maintaining functionality and performance. Clients are encouraged to select an ERP system that aligns with their existing infrastructure and has the capacity to seamlessly integrate with other systems and applications. Moreover, the integration of cloud-based or hybrid ERP solutions can result in benefits related to the cost-effective utilization of client demand elasticity (Johansson & Muhic, 2017). In addition, there is a significance in anticipating and preparing for future needs and requirements by choosing an ERP system that can adapt to new features, modules, or functionalities as client competence and demands evolve.

Secondly, clients should be cautious when it comes to expecting vendor competence, as there might be an overestimation influenced by exaggerated information provided by vendors or advertisers with the intention of finalizing a deal, or by depiction of exceptional or unrealistic scenarios. This inflated expectation is prone to a negative disconfirmation and ultimately has an adverse effect on client satisfaction (Figure 3b). According to the expectation-disconfirmation theory, consumers seek to avert discord between their expectations and product performance by adjusting their expectations to align with perceived product performance (Oliver, 1980). Clients, particularly those lacking firsthand exposure to the outsourced services, should strive to gather information more direct insights or encounters with their IT outsourcing partners. Through this process, a client's expectations of vendor competence will become more realistic, enabling vendors to leverage their actual competence to meet a client’s expectations. This, in turn, not only improves customer satisfaction but also enhances vendor satisfaction.

## 6. Conclusion and future research

This research explored the impacts of client and vendor competences and their moderating effects on the success of outsourced system implementation, taking into account task-technology fit and partnership quality. From a competence perspective, client and vendor competences were construed as higher-order constructs. The study hypothesized the impacts of client and vendor competences on partnership quality and task-technology fit, which subsequently influence outsourced system implementation success in terms of clients’ performance impacts and satisfaction. Drawing from the person-environment fit and expectation-disconfirmation theories, the research postulated the moderating roles of client and vendor competences in explaining the success of outsourced system implementation. The findings suggest that both client and vendor competences play significant roles in the success of outsourced system implementation through the effects of partnership quality and task-technology fit. Their interactions with task-technology fit and performance impact significantly influence the success of outsourced system implementation. Importantly, the finding highlights that task-technology fit does not consistently enhance performance impact if it does not align with the evolving demands of highly competent clients. Moreover, the increase in client satisfaction due to performance impacts is mitigated when clients expect high performance from highly competent vendors. This research makes substantial theoretical contributions by advancing comprehension of the task-technology fit perspective. It leverages the person-environment fit theory to elucidate the moderating impact of individual characteristics (client competence) on the relationship between task-technology fit and user performance. Additionally, it employs the expectation-disconfirmation theory to clarify the moderating effect of vendor competence in explaining the success of outsourced system implementation. The study recommends that clients ensure their outsourced systems possess the requisite scalability and adaptability to effectively respond to changing environments and the diverse user requirements, particularly those of highly competent clients, while also exercising caution in relation to overestimating expectations for vendor competence affecting their satisfaction with the outsourced system.

Every study comes with its own set of limitations. These limitations must be acknowledged and overcome in future research. Firstly, this research solely focused on the implementation of ERP systems. It is worth exploring the application of various technologies since different technologies and systems will result in varying levels of task-technology fit (Wells et al., 2003). For instance, practical tasks coupled with interactive technologies like mobile phones tend to enhance user productivity and satisfaction; however, these technologies may not be well-suited for complex tasks (Hancox & Hackney, 2000). As a result, the role of client competence in the relationship between task-technology fit and performance impacts identified in this study may be modified. Secondly, this study delves into the moderating effects of client and vendor competences separately. Research indicates that disparities in internal and external IT capabilities can lead to conflicts that undermine the success of IT outsourcing (Navarro-Paule et al., 2023). Consequently, it is crucial to analyze how the complementary of client and vendor competences (either client competence exceeds or lags behind vendor competence) moderates the success of outsourced system implementation for future research. Finally, the validity of some model constructs may be questionable. For instance, competence can be subjective and multifaceted, making it difficult to capture its full essence with just a few indicators. While it is possible to utilize a limited number of indicators statistically to ascertain a latent variable for structural equation modeling (SEM) analysis (Hair et al., 2018), expanding the set of indicators used in SEM can indeed enhance the validity of variables and improve the overall model. Future research should incorporate additional indicators, making it more accurately represent complex constructs and ensure that the model aligns better with the realities of the phenomenon being studied.

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## Appendix A. Measurement items of the study constructs

| Constructs | Measurement items | Sources |
|---|---|---|
| *Client Knowledge & Skill* | | |
| *CKS1* | I have knowledge of the specific applications of the ERP system. | Adapted from: Ravichandran & Lertwongsatien, 2005 |
| *CKS2* | I have overall knowledge of organizational operations. | |
| *CKS3* | I have sufficient skills and knowledge to manage the system effectively. | |
| *Client Disposition* | | |
| CDP1 | I participate in determining the system requirements and capabilities for the company's ERP implementation. | Adapted from: Karim et al., 2007 |
| CDP2 | I participate in identifying the input/output of the system needed for the company's ERP implementation. | |
| CDP3 | I am actively involved throughout the ERP system implementation. | |
| *Vendor Knowledge & Skill* | | |
| VKS1 | They have an overall knowledge of the implementation of the ERP system. | Adapted from: Wang & Wang, 2019 |
| VKS2 | They have in-depth knowledge about the functioning of your department. | |
| VKS3 | They have expertise in the specific application area of the ERP system. | |
| *Vendor Disposition* | | |
| VDP1 | They provide their services at the times they promise to do so. | Adapted from: Wang & Wang, 2019 |
| VDP2 | They give prompt service to you or your team. | |
| VDP3 | They are always willing to help you or your team. | |
| *Task-Technology Fit* | | |
| TTF1 | The ERP system fits well with the way I work* | Adapted from: Goodhue & Thompson, 1995 |
| TTF2 | The ERP system helps to complete my task. | |
| TTF3 | The ERP system is compatible with my work style. * | |
| TTF4 | Using the ERP system enhances my task effectiveness. | |
| TTF5 | The ERP system provides the functionalities necessary to complete my tasks. | |

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| | | |
|---|---|---|
| *Partnership Quality* | | |
| PNQ1 | I seldom have conflicts with the ERP service providers. | Adapted from: Ravichandran & Lertwongsatien, 2005 |
| PNQ2 | I get timely information from the ERP service providers about unexpected problems. | |
| PNQ3 | I can rely on the ERP service providers to respond to my technology needs in a timely and effective manner. | |
| PNQ4 | I have a very trusting relationship with the ERP service providers. | |
| PNQ5 | I have a long-term partnership with the ERP service providers. | |
| *Performance Impact* | | |
| PMI1 | The ERP system increases my overall performance. | Adapted from: Goodhue & Thompson, 1995 |
| PMI2 | The ERP system increases the quality of my work. | |
| PMI3 | The ERP system helps me to work more effectively. | |
| PMI4 | The ERP system decreases the error rate of my work. | |
| PMI5 | The ERP system increases the overall company's productivity. | |
| *Client Satisfaction* | | |
| CSF1 | I perceive that the ERP system meets intended functional requirements. | Adapted from: Simon et al., 1996 |
| CSF2 | The information provided by the ERP system meets my expectations. | |
| CSF3 | I am satisfied with the overall quality of the ERP systems. | |
| CSF4 | I am satisfied with the overall quality of the ERP service providers' work. | |
| CSF5 | I am satisfied with the completeness of the ERP system output. * | |

* Item loadings lower than 0.7 were excluded from analysis.

## Biographical notes

**Boonlert Watjatrakul** is an Associate Professor of Information Technology at King Mongkut's Institute of Technology Ladkrabang, Thailand. He holds a PhD in Information Systems from the University of Queensland, Australia, supported by a scholarship. He also earned a Master of Business Administration from Cleveland State University and a Certificate of Professional Designation in Systems Analysis from the University of California Los Angeles, USA. His research focuses on IT outsourcing, IT management, e-learning, and e-business adoption. He has published extensively in international peer-reviewed journals.

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