Eveliina Alarinta

Testing-as-a-Service Market Situation in Finland in Terms of Quality

UNIVERSITY OF VAASA
Industrial Engineering and Management
Author: Eveliina Alarinta
Thesis Title: Testing-as-a-Service Market Situation in Finland in Terms of Quality
Degree: Master of Science in Economics and Business Administration
Subject: Industrial Management
Supervisor: Ville Tuomi
Year of Graduation: 2024 **Page Count:** 59

ABSTRACT:
This thesis explores the Testing-as-a-Service (TaaS) market in Finland, with a particular focus on service quality and adoption within the software testing landscape. As software development becomes increasingly complex, driven by the adoption of cloud services, the need for efficient software quality assurance (QA) has grown. TaaS, a cloud-based solution, offers organizations flexibility and scalability by outsourcing testing services on demand. The study aims to answer a research question: What is the current Testing-as-a-Service Market Situation in Finland in Terms of Quality?

This research was conducted in collaboration with Fellowmind Finland Oy Ab, which offers, among other things, a broad range of services including ERP, data analytics, CRM, AI solutions, cloud security, IT infrastructure, project management, business planning, application development, and modern workplace solutions. The research is based on a survey, supplemented by two interviews with industry professionals. The survey provides a broad overview of TaaS adoption in Finland, focusing on aspects such as service quality, scope of testing, and current usage rates. The interviews offer deeper qualitative insights into the experiences of professionals who have used or considered using TaaS solutions, enriching the data from the survey.

The thesis is structured as follows: Chapter 2 reviews literature on software testing and QA, including testing types, automation strategies, and tools, and discusses the role of TaaS in continuous software engineering. Chapter 3 outlines the methodology used, detailing the survey process and interviews. Chapter 4 presents and analyzes the results from the survey and interviews. Chapter 5 summarizes the conclusions and suggests areas for future research. Finally, all the appendices can be found at the end of the study.

This research aims to explore the TaaS market in Finland while also contributing to the broader discussion on software testing practices. It provides practical insights for companies considering TaaS as part of their QA strategy, offering recommendations for enhancing software quality through cloud-based testing solutions.

KEYWORDS: Testing-as-a-Service (TaaS), Software Testing, Quality Assurance (QA), Cloud-based Testing, Test Automation, Continuous Software Engineering, Survey, Interview

Table of Contents

Figures

Tables

1 Introduction

The rapid development of software development and the proliferation of cloud services have brought with it the complexity of systems and the need for more efficient methods to ensure software quality. As organizations across industries continue to rely heavily on both software systems and cloud infrastructure for their operations, the importance of software testing and quality assurance (QA) has never been more critical. Testing plays a key role in identifying defects, ensuring reliability and maintaining performance, so it is an essential part of the software development life cycle. One emerging solution in this area is Testing-as-a-Service (TaaS), a cloud-based model where third-party vendors provide testing services to organizations on demand, offering both flexibility and scalability.

This thesis focuses on the Testing-as-a-Service market situation in Finland, especially in terms of quality. The goal of the research is to provide insights into the benefits, challenges and perceptions related to the use of TaaS in the country's software testing environment. In addition, it will be determined whether TaaS meets the companies' quality expectations and how the service integrates into their broader software development and quality assurance processes. Various implementation challenges, for example information security issues, are also considered.

The research method is a survey, which is complemented by two interviews with professionals in the field. The survey aims to get a broad overview of the current state of TaaS implementation, especially in Finland, focusing on key aspects such as service quality, scope of testing, to what extent TaaS meets the needs of the organization and its current usage rate among individuals. This includes examining the current use of TaaS and identifying factors that may influence or limit its use. The interviews supplement the survey material by providing a deeper qualitative insight into the specific experiences of professionals who have used or are considering TaaS solutions.

The structure of this thesis is as follows: Chapter 2 provides a comprehensive review of software testing and quality assurance literature, covering different types of testing, automation strategies and tools. It includes a systematic literature review, a structured academic method for identifying and evaluating all relevant literature on a given topic in order to draw conclusions related to a research question (Technische Universität Berlin, 2024). In addition, it learns about service testing (TaaS) and its role in continuous software engineering. Chapter 3 outlines the methodology used in this study and details the survey process, interviews and data analysis methods. Chapter 4 presents the results of the survey and interviews, as well as a detailed analysis of the findings. Finally, chapter 5 concludes the thesis by summarizing the key insights of the research, considering the implications of implementing TaaS in Finland and proposing opportunities for future research.

The research aims to answer the research question: What is the current market situation of service testing services in Finland in terms of quality? This research contributes to the ongoing conversation about software testing practices and provides valuable insights for companies considering TaaS as part of their software testing strategy. By studying the Finnish TaaS market, this thesis aims to offer practical recommendations for improving software quality using cloud-based testing solutions.

2 Literature review

This chapter addresses a range of topics including Software Testing and Quality Assurance, Types of Software Testing, Test Automation Strategy, Testing Tools, Scope, Test Automation Approach, Objectives, Risk Analysis, Test Automation Environment, Execution Planning, Naming Conventions for Tests, Release Control, Failure Analysis, Examination and Feedback, and Testing-as-a-Service. Additionally, it explores Cloud Computing and Manufacturing, Cloud Manufacturing, and Resource Scheduling. The concluding sections discuss Advanced Manufacturing Technologies, the Impact of Artificial Intelligence on Various Sectors, and Computer-Integrated Manufacturing (CIM).

2.1 Software Testing and Quality Assurance

Software testing plays a vital role in improving software quality and reliability. Adopting cloud-based testing offers cost savings, flexibility, and improved efficiency compared to traditional methods. By eliminating manual setup and maintenance, cloud testing streamlines processes and enhances performance at a lower cost. The availability of software testing services through cloud platforms ensures that companies across different industries and projects can access these services with ease. Additionally, this setup supports on-demand usage, catering to different needs as they arise. (Janani, V., & Krishnamoorty, K. 2015)

In the study by Mishra, D., Ostrovska, S., & Hacaloglu, T. (2017), from a performance standpoint, automated testing demonstrates superior effectiveness compared to structural and functional testing methodologies. Additionally, a significant correlation has been identified among these three approaches. Having a strong programming background helps greatly with structural and automated testing, though it doesn't necessarily affect the results of functional testing. The findings also encompass an examination of diverse pedagogical approaches employed within the course, coupled with an analysis exploring the potential relationship between students' gender and

their performance in the software testing curriculum. Notably, the results reveal no significant disparity in performance testing between male and female testers.

Software testing stands as a pivotal and indispensable facet within the realm of software development. It serves as the predominant method for ensuring quality assurance and control within software development enterprises. In contemporary contexts, the burgeoning size and intricacy of software applications necessitate heightened investments of time and resources in the generation and execution of test cases. (Ali, A. et al 2022)

Furthermore, the expertise of seasoned testers is indispensable for the meticulous generation and execution of test cases, ensuring the precision and reliability of test outcomes. Additionally, the development of numerous software applications often occurs under constraints pertaining to resource availability, budgetary limitations, and stringent time-to-market demands. Consequently, the comprehensive testing of software applications within such constrained temporal and financial parameters poses a significant challenge, thereby impinging upon the sustained quality and dependability of software applications. (Ali, A. et al 2022)

2.1.1 Types of Software Testing

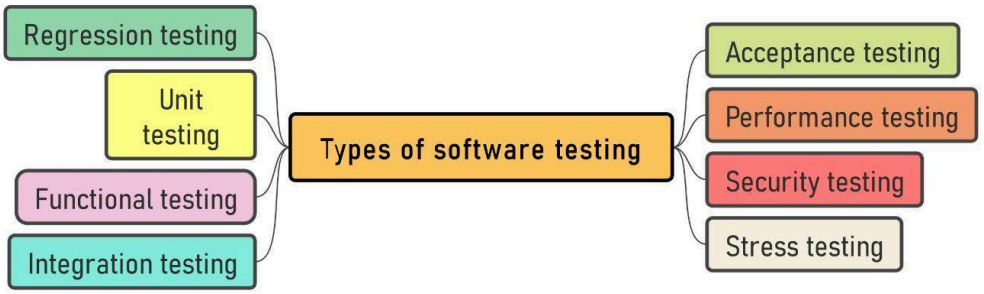

Figure 1: What is Testing as a Service (TaaS)? - TechTarget https://www.techtarget.com/searchcloudcomputing/definition/Testing-as-a-Service-TaaS. Retrieved 26.4.2024.

Regression testing verifies whether the incorporation of novel functionalities results in a degradation of the operational integrity of an application. This iterative process is conventionally executed subsequent to the implementation of each software build. (TechTarget 26.4.2024) This test can take a lot of time and resources, so it should be automated if possible (Tamagnan et al., 2023). Unit testing guarantees the proper functionality of each discrete unit or element within a system. This process is commonly undertaken throughout the application development phase to ascertain that each component operates according to its designated specifications (TechTarget 26.4.2024). Functional testing evaluates every function against the established functional requirements. An example of this is the black-box test, a prevalent method used to assess the functionality of software without examining its internal structure. (TechTarget 26.4.2024; see also Severp & Lelli 2023).

Integration testing involves combining two or more modules of an application to verify their collective functionality and compatibility, simply striving to ensure components work together. Stress testing, on the other hand, evaluates the resilience of software systems by subjecting them to increasing loads until they approach or exceed their capacity limits. Security testing validates the absence of possible vulnerabilities, identified flaws, and security issues within software systems, thereby safeguarding user systems and data from potential threats. Performance testing can be described to evaluate an application's efficiency, velocity, and ability to handle a specified workload. (TechTarget 26.4.2024). Emphasis has been in efficiency (Imran et al., 2024). Acceptance testing scrutinizes the entire system against predefined requirements to validate project fulfillment (TechTarget 26.4.2024), and it determines fulfillment of end-users requirements (Fischbach et al., 2023).

2.1.2 Test automation strategy

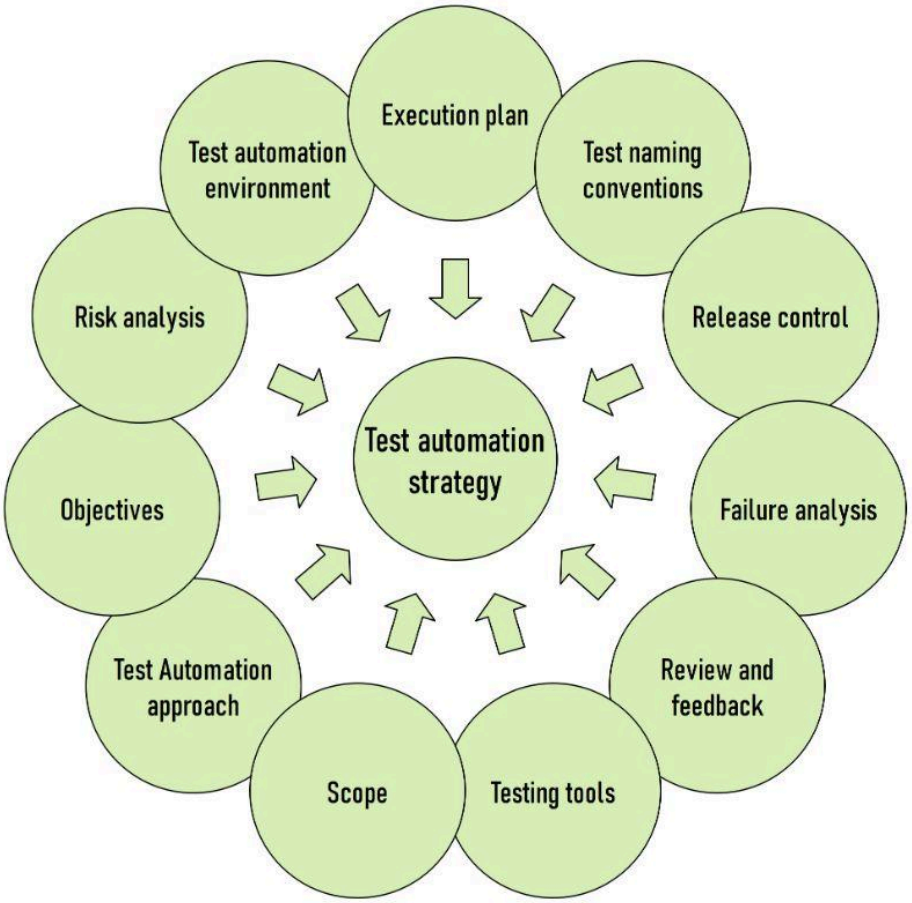

Figure 2: Test automation strategy (Fellowmind 2024).

There are only six best practices in test automation, which are based on academic research and definition of an effective test automation strategy is one of them. There should also be enough resources, competent test professionals, selection of the right test tools and good test environments (Wang et al., 2022). Test automation strategy consists of different kinds of tasks (Francalino et al., 2018)

2.1.3 Testing tools

When selecting the appropriate testing tool, it is crucial to consider its impact on the automation strategy. The selected tool can significantly affect the project's end-result. Using a tool that is later proven to be mistaken can lead to wasted time and resources. On the other hand, using the correct tool can remarkably increase productivity and proficiency for the project. It is also prudent to consider licensing fees, maintenance charges, training and support, extensibility, performance and steadiness when selecting the right tool for the project. (Fellowmind 2024)

2.1.4 Scope

Each sprint is defined as the scope of the project when also considering timetables and project milestones in the point of view of automation. Every person in the team, including for example testers, product owners and developers should have the same picture of the goal of the project when considering the it’s scope. Working in the same teams instead of different changing individuals can strengthen the collaboration and can have a positive effect on the project's end-results and testing. (Fellowmind 2024)

At this point the test plan should be analyzed and it should be decided, what cases can be automated and which ones require manual work. Usually the practice is to automate approximately 80% of the test cases, if they meet the automation testing criteria. (Fellowmind 2024)

2.1.5 Test automation approach

Test automation approach includes three main factors: Processes, technology and positions. In processes, the key questions are: What is the optimal time to develop automated test cases? When are the characteristics of the cases ready to be automated? Which characteristics still require manual testing? Who is responsible for the maintenance issues? How are the end-results examined? (Fellowmind 2024)

In the technology part, it is crucial to consider how the platform syncs with the specific technologies. Web-based applications, desktop-based applications and mobile apps may be the ones to be automated. It is significant to choose the correct automation platform that will sync with key business strategies and make the project as effective as possible. In a project with many diverse components, it is important that every person needs to identify their role in the project at any occasion, especially in the automation perspective. The lead of the automation is in charge of overall coordination and overseeing the selected tasks. The selection of the specific platform and choosing the framework as well as taking care of the team are key factors of the automation leader. Test case designer is responsible for establishing the test scenarios. The reviewer is responsible for accuracy, effectiveness and fulfillment of the project. Other positions of the project can be Automation Developer, Test Data Manager, and Test Environment Manager. (Fellowmind 2024)

2.1.6 Objectives

In the optimal situation, the key objectives of the project are: Clarity, specificity, substantiality, up-to-dateness, and timeliness. These factors can affect the achievement of the business goals and measurement issues. In the test automation it is also significant to decrease testing time, expenses, unnecessities, and manual steps. On the other hand, objectives strive to increase rapidity as well as improve features and test coverage. One model is for example to set a target to improve performance by 70% at the same time as decrease 40% in testing costs. When considering objectives as test

automation perspectives, one should also not forget the company's KPIs and OKRs. (Fellowmind 2024)

The goal of the setting up objectives is to free up time to focus fully on the testing results and its measurement. Some models to set objectives for test automation strategy: Increase the test coverage by 50% by the end of the year, reduce the time of regression testing by 70 % by the end of the six months, improve accuracy of the specific test by 40% within the next three five months, increase the efficiency by 30% of the test implementation within the next three months. (Fellowmind 2024)

2.1.7 Risk Analysis

Risk analysis is an essential part of the project planning in test automation. To be fully purpose-built, it is needed to update it periodically. This process brings along efficiency and activity for the project. In risk analysis is typically created a list including the following items: Explanation and associated metadata, severity, probability, mitigation, and cost forecast. Explanation and associated metadata can help the team to grasp what kind of risk is involved? Severity means, what consequences might be, if the risk scenario occurs in reality. What is the level of damage that might take place? (Fellowmind 2024)

Probability is evaluating how likely is the risk to happen and being prepared how to react effectively with low damage impact. Reduction is assessed what can be done to mitigate the negative impacts for the project. Usually there are specific actions created for this part, which should be then executed. When planning to mitigate each risk, it is essential to take account of costs in both situations in the cost forecast.: If it is needed to take some action or if it is not. This can also help to allocate resources in advance. Seriousness and probability can be visually described like the following: three colored balls out of three means that the issue is very severe or very likely, one colored ball out of three means that the issue is not serious or very likely to occur. (Fellowmind 2024)

2.1.8 Test automation environment

In a test automation environment, the most important factors are coverage, agility, processing, availability, data storing, usage of production data, as well as data cleanup and masked data issues. In software companies, consistent and reliable testing environments are an essential part of the business. In test automation, a general rule is that pre-defined inputs will generate known outputs. Also, especially when copying data from production, one should be careful about data storing, possible anonymization of the used data and data cleaning after the project is complete. (Fellowmind 2024)

One of the well-developed and clearly established release methodologies is DevOps. The key factors for rapid releases in DevOps are early and continuous integration and deployment throughout the development process. Simply put, the better and more stable the test environment, the smoother and more predictable the test automation will be. (Fellowmind 2024)

2.1.9 Plan for execution

Execution plan includes day-to-day execution phases and processes about test automation. As a general rule automated test cases should run and be confirmed as many times as possible to validate that they work as expected. To make processes smoother test cases should be as reliable as possible, because any error can be complex and tedious to fix. To avoid such unpleasant situations in test automation, it is important to outline a series of practices. These recommendations should outline the methods for test cases to identify and interact with elements within the application being tested. The details of these recommendations will vary based on the particular application. (Fellowmind 2024)

Test case execution should be managed either by a pipeline orchestrator, like Jenkins, TFS, Bamboo, or TeamCity, or by a scheduling tool. These servers are frequently used to guide the execution process within pipelines. Regression tests can be executed either

during a build or deployment process, or at a predetermined time each day. Opt for a setup that enables parallel execution of test cases to deliver faster feedback to the development team. Establishing a clear execution plan will enhance the efficiency and effectiveness of your test automation efforts. (Fellowmind 2024)

2.1.10 Conventions for naming tests

A solid approach to naming tests should incorporate the number of the test case or test ID, the specific feature or module under examination, and a clear indication of the test case's purpose. You may also choose to denote whether it's a positive or negative test. (Fellowmind 2024)

To maintain uniformity and clarity, one should adhere to these guidelines: Craft a name that logically integrates the elements mentioned earlier. Embrace a uniform and standardized naming convention throughout your test process. Steer clear of excessively detailed names. Ensure distinctions in the name for similar test cases that differ only slightly. (Fellowmind 2024)

The main benefits of having well-organized and predefined naming rules: It facilitates the clear identification of tests within the folder arrangement determined by names, action taken, or test case ID. Furthermore, it streamlines the process of identifying malfunctioning features during test execution, as recognizing a failed test can be swiftly achieved by examining the test name rather than combing through the complete test scenario. (Fellowmind 2024)

2.1.11 Release control

Within a release pipeline, determining whether to proceed with a build relies on both automated procedures and human assessment. While certain tasks can be automated, others necessitate human input. As a result, the ultimate decision usually blends automated outputs with manual evaluation. To guarantee well-founded release

determinations, it's crucial to integrate test automation findings. This might involve permitting releases solely upon successful completion of all regression tests or having the lead tester review results. Such an approach fosters comprehensive testing, ensuring potential issues are identified before the release stage. (Fellowmind 2024)

Inspecting application logs is a common practice of making release decisions additionally of regression tests. If the regression tests thoroughly cover the application, any issues unrelated to the user interface should appear in the log records. This will offer further understanding of the application's behavior and aid in detecting any issues that might have been overlooked earlier. Ultimately, the decision to release should rely on both automated and manual testing, emphasizing comprehensive testing of the application to ensure all issues are detected and fixed prior to release. (Fellowmind 2024)

2.1.12 Failure analysis

A crucial but often overlooked aspect of a test automation strategy is having a plan for analyzing and identifying failing test cases. The resolution process can be unexpectedly lengthy, encompassing notification of the failure, and the subsequent description, understanding, and acceptance of the fix in the development backlog. (Fellowmind 2024)

It is essential to have a well-defined process for analyzing and fixing failing test cases to conserve time and minimize frustration for the development team. A result-oriented approach, with measurable outcomes for each test run, can also enhance the effectiveness of the automation processes in identifying issues. (Fellowmind 2024)

Dashboards can help stakeholders measure and evaluate software through test metrics, enabling teams to assess its quality before market launch. Using a result-oriented method and tracking these metrics ensures thorough testing and compliance with necessary quality benchmarks. (Fellowmind 2024)

2.1.13 Examine and feedback

Upon drafting a test automation plan, it is imperative to conduct a thorough review and secure approval from the entire development team. This process ensures that all team members comprehend and align with the strategy's key goals and objectives. (Fellowmind 2024)

To foster continuous learning and enhancement, it is vital to include feedback from team members, stakeholders, colleagues working with automated processes. Integrating this feedback helps identify aspects for improvement and adjust the plan accordingly. (Fellowmind 2024)

Documenting insights gained during software automation is important for future reference, helping the team avoid repeating errors. Continuously improving the test automation plan through feedback and learning is indispensable for success. Embracing a mindset and habit of ongoing learning ensures the automation strategy continues to be effective and efficient in attaining the desired objectives. (Fellowmind 2024)

2.1.3 Testing-as-a-Service

Testing-as-a-Service (TaaS) is a cloud-based software testing solution that utilizes the computing capabilities offered by the cloud. Essentially, TaaS has the flexibility to accommodate extensive and ever-changing workloads, operating within a distributed setup utilizing numerous processors. These processors are capable of facilitating simultaneous and dispersed test execution and analysis. (Wei-Tek T. & Guanqiu Q. 2016) TaaS is vital for maintaining software reliability and quality, particularly in projects with tight schedules. It not only cuts costs but also enhances productivity compared to traditional testing methods. (Girardon, G. et al 2020)

Testing-as-a-service (TaaS) operates as a cloud-based business model where a provider handles all the testing tasks and activities for web-based software or applications. They conduct these tests within a cloud infrastructure and simply offer them as a service to their clients. One example of using TaaS can be, for instance, mobile application testing. Mobile testing executed in a cloud environment is necessary to address significant challenges in testing mobile applications. These challenges might comprise: Expensive current mobile testing methods and setups, insufficient testing resources and tools for assessing mobile scalability, as well as the complexity and difficulty of mobile testing due to the diverse range of mobile devices, operating systems, browsers, and settings. (Chuanqi T. & Jerry G. 2017)

Testing as a Service (TaaS) emerges as a service model encompassing automated execution of various testing functions, encompassing the generation of test cases, their execution, subsequent analysis of outcomes, and the generation of comprehensive test reports. Within this framework, the provisioning of Performance testing is facilitated through the utilization of cloud resources. From a pragmatic standpoint, performance testing serves to scrutinize the response patterns exhibited by the Application Under Test (AUT) when subjected to diverse loads generated by concurrent users. (Ali, A. et al 2022)

Testing-as-a-service solutions can be used also in fuzz testing. Fuzz testing can be used in automated testing in consistent web-based application programming interfaces (APIs) specifications, such as SOAP, OpenAPI and GraphGL. Fuzz testing services offered through the internet cloud can help manage scalability issues, but they aren't always practical because they need users to upload their software artifacts to outside systems. Usually, company rules stop them from sharing these artifacts with third parties due to worries about expenses, protecting intellectual property, and maintaining security. (Mahmood, R. et al 2022)

Volkswagen AG has established its hybrid cloud products and services with the objective of achieving a markedly reduced time-to-market and ensuring a superior quality standard. To fulfill these objectives, there is a pressing need to accelerate extant testing methodologies, thereby preempting any potential impediments to the expeditious deployment of novel features. In pursuit of expediting the delivery of products and services, the implementation of Testing as a Service has been undertaken utilizing lean/agile methodologies and seamlessly integrated into the Continuous Integration/Continuous Deployment (CI/CD) pipeline of the Volkswagen Group IT Cloud. (Poth, A. et al 2018)

2.1.4 Continuous Software Engineering

In its brief evolution, the realm of software development has often been marked by detrimental disjunctions among pivotal endeavors such as strategizing, constructing, and implementing. This issue is compounded by sporadic and irregular execution of undertakings like planning, testing, amalgamation, and rollouts. Various nascent trends and practices have surfaced as endeavors to mitigate these challenges. Notably, Continuous Integration stands out as a methodology aimed at obviating interruptions between developmental phases and deployment. Continuousness doesn't necessitate rapidity; instead, it is viewed as a holistic endeavor by the researchers. (Fitzgerald, B. and Stol, K-J. 2017)

The continuous software engineering (CSE) model is gaining popularity in modern development practices, where the interleaving of design and runtime activities is caused by the continuous progression of different software systems. In other words, Continuous Software Engineering integrates business strategy (such as requirement engineering), development, and operations seamlessly along a continuous spectrum. (Eramo et al. 2024)

Software testing constitutes an integral component of the Continuous Software Engineering process. In addition to Continuous testing, it includes Continuous Delivery,

Continuous Deployment, Continuous Integration, as well as Continuous Feedback. There are some significant benefits of Continuous Software Engineering, such as reducing code building time, freeing up time for testing, enhancing status reporting, providing visibility, expediting the release process, delivering higher product quality, aiding in the automation of testing and development, as well as improving the overall dependability of the deployment process. (Dheeraj C. & Kalpana S. 2019)

2.2 Cloud Computing and Manufacturing

Cloud computing offers businesses the option to outsource computing services at a reduced expense, which has made it a favored solution for many companies. Over the past few years, cloud storage has become increasingly popular due to its benefits in upkeep, speed, assistance, affordability, and dependability compared to conventional storage approaches. Moreover, cloud computing enables functions like resource allocation, workload distribution, capacity planning, and job-based resource allocation. This revolutionary influence highlights the importance of cloud computing in today's digital environments, providing organizations with unparalleled efficiency and scalability in resource management. (Goswami et al., 2024) Numerous cloud service providers offer tools for cost management, enabling businesses to monitor their current expenses and predict future costs based on their usage patterns. One of the key benefits of cloud computing is to rapidly scale resources up or down to meet changing demand. Cloud systems are built for reliability, ensuring they can endure and recover from disasters and complete system failures. (Ulasien, M. 2023).

Although cloud computing is widely recognized as a solution for scalability requirements, the enduring complexity in cloud configuration and operation frequently may emerge as an obstacle (Werner, S., & Tai, S. 2024) The significance of cloud computing's security has been underscored in various studies and literature. By integrating secure multiparty computation with cloud computing, a heightened level of data protection can be achieved while preserving the advantages inherent in cloud computing infrastructure (Luo et al., 2024).

Testing-as-a-service (TaaS) has emerged with technological advancements to address the growing needs in software testing, driven by organizations adopting new technologies and customizing software to meet their specific organizational requirements. In cloud computing with TaaS, the physical storage hardware is integrated with the operating system at the data center level, whereas the virtual machine encompasses the cloud administrator and automated systems. The functioning of cloud TaaS relies on asset scheduling, which aids in mitigating potential issues such as resources going offline or experiencing errors and delays in execution. (Sharma et al., 2022)

2.2.1 Cloud Manufacturing

In the context of servitization, cloud manufacturing introduces a novel business framework that facilitates the evolution of the manufacturing industry from a focus on production to an emphasis on services, thereby fostering the adoption of a pay-per-use model. Cloud manufacturing services encompass various components such as design, production, simulation, assembly, testing, logistics, management, and integration as a service. By leveraging multiple cloud manufacturing services, clients have the ability to request tailored and on-demand solutions that align with their specific requirements. Essentially, individuals or entities with innovative design concepts can access a comprehensive suite of production services until the final product is delivered. This paradigm benefits both small-scale enterprises lacking extensive manufacturing infrastructure and large corporations with underutilized production capacities. (Cimini, C., Lagorio, A., Pinto, R., Pezzotta, G., et al. 2023.)

Over the past decade, cloud manufacturing (CMfg) has garnered significant interest from both academia and industry on a global scale. There is a consensus that the establishment and examination of cloud manufacturing architecture (CMfg-A) serve as foundational steps in the development and implementation of CMfg systems. In the research conducted by Lim, M. K., Xiong, W., & Wang, C. (2021), it is observed that

CMfg-A (Cloud Manufacturing Architecture) resources undergo a progression wherein they transition from tangible to intangible and intelligent forms. Concurrently, CMfg-A technology evolves from conventional cloud computing-based approaches to more advanced manufacturing technologies. Furthermore, the application scope of CMfg-A expands progressively from conventional manufacturing sectors to burgeoning manufacturing industries. Moreover, upon scrutinizing the constituent elements, interrelations, structure, and functionalities of CMfg-A, this investigation reveals an ongoing transformation toward a new generation characterized by integrated, intelligent, innovative, and sustainable development trends. A research underscores the utility of analyzing developmental trajectories and internal attributes of the architecture in facilitating the design of a more efficacious architectural framework.

2.2.2 Resource Scheduling

DEA (Data Envelopment Analysis) is a method used to compare how effectively different operating entities, known as DMUs (Decision Making Units), utilize similar resources to produce similar products or services. It's a way of assessing the efficiency of these entities in relation to each other without making specific assumptions about the functional form of the relationship between inputs and outputs. (Chu, J., Wu, J., Zhu, Q., & Sun, J. (2016) One of the DEA's, Charnes, Cooper & Rhodes (CCR), posits a constant scale efficiency assumption for decision-making processes. (Abdolmaleki, M., Mamdoohi, A. R., & Emami, M. (2024) However, this conventional production possibility set is inadequate for assessing the efficiency of RN-DMUs (Resource-Node Decision Making Units) within a private cloud environment. This is because it lacks the capability to incorporate non-discretionary inputs such as CPU performance and internal memory capacity, as well as undesirable outputs like the time required by RN-DMUs.(Chu, J., Wu, J., Zhu, Q., & Sun, J. 2016)

Resource scheduling in Testing as a Service (TaaS) is one of the most difficult tasks in allocating resources to essential tasks based on the quality standards for applications and projects. Karthik and Sekhar (Karthik P. and Sekhar K. 2021) studied Resource

scheduling in relation to four different Artificial Intelligence Algorithms: DRLTC (deep reinforcement learning for Taas cloud), LJF (longest job first), SJF (shortest job first) and Tetries. Students randomly created a few jobs and cloud assets; 80% of the generated data are allocated for training purposes, while the remaining 20% are designated for testing. The result indicates that when there are only a few small jobs waiting to be scheduled, all four schedulers perform similarly, with almost the same number of delayed jobs. However, as the number of jobs to be scheduled increases, SJF, LJF, and tetries tend to have more delayed jobs compared to DRLTC. In addition, DRLTC is the only algorithm that uses training phases when more iterations are done. Also, the typical job slowdown accounts for about 10% of the total number of jobs.

2.3 Advanced Manufacturing Technologies

This section explores the transformative potential of advanced manufacturing technologies, focusing on Quality, the Impact of AI on Various Sectors, and Computer-Integrated Manufacturing (CIM). Quality management significantly enhances performance by monitoring production factors and ensuring optimal IoT network performance. AI revolutionizes various sectors by enabling continuous learning, analyzing data, and enhancing service quality. High AI service quality improves collaboration but can be influenced by how well AI functions align with user abilities. CIM integrates manufacturing processes through advanced software, boosting efficiency. IoT-based CIM systems with RFID technology exemplify progress but require rigorous testing for reliability.

2.3.1 Quality

Numerous research findings indicate that the implementation of quality management practices has a substantial impact on a company's overall performance. (Agrawal et al., 2023) When discussing quality standards in manufacturing, it's crucial to identify the factors that determine the final product's quality and to monitor them throughout the production process. The issue of managing processes when an automatic machine operates under varying conditions, particularly when certain parameters fluctuate

significantly, remains largely unexplored in existing literature. This goal becomes increasingly difficult when the critical process variables cannot be directly measured. (Bono et al., 2023)

Quality of Service (QoS) refers to the network's capability to deliver a reliable and appropriate level of service to various applications and users. It encompasses several factors such as latency, bandwidth, reliability, and service availability. Particularly in the Internet of Things (IoT) networks and multimedia communication, essential aspects of Quality of Service include the ability to handle large volumes of data, minimize delays, and ensure consistent and high-quality service, especially for real-time audio and video traffic. Thus, the aim of QoS is to ensure efficient network operation and provide an optimal user experience for all users, even in the presence of network congestion or varying service quality. (Vijaykumar, S., & Thyagaraj, S. P. 2023)

In simpler terms, one of the widely respected explanations of quality comes from David A. Garvin, a professor at Harvard Business School in 1984. He outlined eight different aspects that contribute to defining quality: Performance, Features, Reliability, Conformance, Durability, Serviceability, Aesthetics, and Perceived quality (Basu 2023).

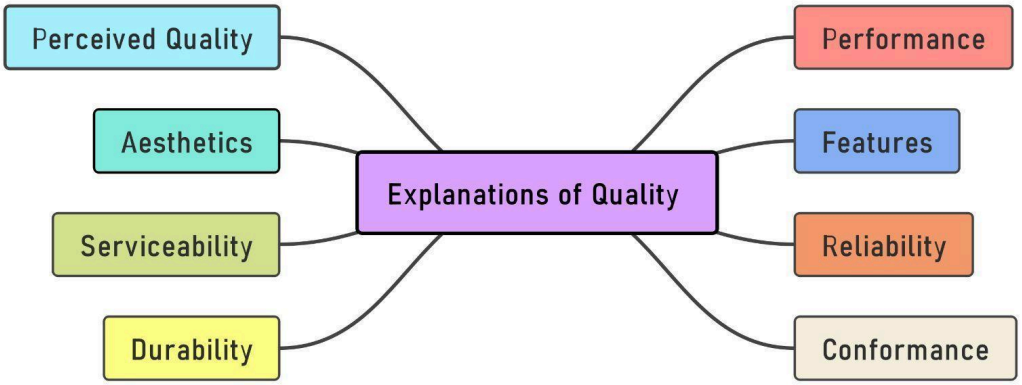

Figure 3: Garvin's Product Quality Dimensions (Basu 2023).

Performance relates to how effectively a product accomplishes its intended goals or functions. For example, in terms of return on investment. Features are extra qualities that enhance the fundamental performance of a product, like tinted glass windows in a car. Reliability means how well a product can consistently perform throughout its entire lifespan. Conformance means meeting the defined specifications of a product, typically expressed as numerical values. Durability refers to how well a product holds up under pressure or strain without breaking or malfunctioning. Serviceability indicates how easy it is to repair or maintain a product when needed. Aesthetics encompass sensory attributes like appearance, sound, taste, and smell. Perceived quality relies on the judgment and opinion of customers. (Basu 2023)

The quality of the supply chain improves when supply chain information is well integrated, the supply chain demonstrates resilience, and relationships within the supply chain are effectively managed. Using data-driven approaches improves supply chain processes by analyzing supply chain data to enhance planning and operations.

Supply chain companies are exploring various digital technologies to boost their performance and stay competitive in the market. Quality management is a crucial component of supply chain management. (Agrawal et al., 2023)

The challenges hindering the advancement of digital technologies, particularly those utilizing AI in audit activities, include risks related to the quality of software being produced, the thoroughness of data obtained from audit examinations, and the ease and effectiveness of utilizing information technologies in the field of quality management audits. Also, The study indicates that there is a definite need for proactive management of analytics in order to establish trust in a company. (Semenova et al., 2023)

We are currently experiencing what is often called Industry 4.0, which is considered the fourth industrial revolution. Quality 4.0 is essentially about integrating quality management practices with the latest advancements of Industry 4.0, aiming to guide organizations towards operational excellence. (Juran 2019) Industry 4.0 means technology from drones to virtual assistants and software that can translate or invest. This progress has been propelled by exponential growth in computing capabilities and the abundance of data available, spanning from programs designed to uncover new medications to algorithms tailored to forecast our cultural preferences. (World Economic Forum 2016)

Soundarayaa et al. (2024) discuss the importance of Quality of Service (QoS) in Vehicular Ad Hoc Networks (VANETs), which are crucial for the development of intelligent transportation systems. Their research proposes a novel routing protocol that utilizes a specific algorithm to ensure optimal routing and improved QoS in vehicle-to-vehicle communication. This protocol incorporates an algorithm and a caching mechanism to reduce communication overhead and expedite data transmission. Simulation results demonstrate that this approach outperforms previous

methods by reducing communication overhead, minimizing delays, and increasing throughput.

As in Chiarini study table 5 indicates (Chiarini 2020) important themes and concerns related to Quality 4.0 are: “Creating value within the company through quality (big) data, analytics and AI, Developing Quality 4.0 skills and culture for quality people, Customer value co-creation, and CPS (Cyber Physical Systems) and ERP (Enterprise Resource Planning) quality assurance and control”

“Creating value within the company through quality (big) data, analytics and AI” meaning efficiently gathering and exchanging the necessary information (where it comes from, what it entails, how it's processed, and who needs it). This involves using advanced tools such as analytics, predictive software, and AI to solve problems and make decisions more effectively., “Developing Quality 4.0 skills and culture for quality people” meaning involving developing skills to gather, analyze, and understand large sets of data, then using that insight to make informed decisions and take action, benefiting both workers and experts. Additionally, it's about fostering and advancing a culture that values quality and embraces the principles of Industry 4.0., “Customer value co-creation”that indicates digitizing services and automatically collecting vast amounts of data from customers to enhance the entire process from design to production. This leads to better customer relationships and experiences by utilizing technologies like Cyber-Physical Systems (CPS), Customer Relationship Management (CRM), Artificial Intelligence (AI), and social media platforms., “CPS (Cyber Physical Systems) and ERP (Enterprise Resource Planning) quality assurance and control” meaning keeping track of the condition and journey of a product, automatically gathering data on inspections, audits, non-compliant products, and calibration results. This data is managed using Product Lifecycle Management (PLM) and Manufacturing Execution System (MES) software, streamlining the document control process through automation. (Chiarini 2020)

It is found in the study (Angioni M., and Musso F., 2020) that underutilization of Industry 4.0 technologies across various solutions. The projects reviewed primarily focus on isolated technological applications such as remote assistance and sensors, rather than integrating them into a cohesive system encompassing medical devices, control systems, and data analysis supported by artificial intelligence and machine learning. Additionally, the utilization of robotics for assistance tasks, facilitated by IoT systems, represents an untapped frontier. These observations suggest that the transformative potential of Industry 4.0 technologies has yet to be fully realized. Achieving this potential necessitates the adoption of a different organizational model capable of delivering efficiency and cost reduction benefits far beyond what individual technological applications can offer. (Angioni M., and Musso F., 2020)

When a company integrates Quality Management Systems (QMS), Information and Communication Technologies (ICTs), and Lean Six Sigma (LSS) tools, it significantly enhances various performance metrics, such as quality performance, delivery performance, sales turnover, and inventory levels. A study found that, although there is no clear correlation between the type of system used and performance indicators, the combination of QMS, LSS tools, and ICTs leads to substantial improvements in most performance indicators (Yadav et al., 2020).

Deep learning methods, particularly neural networks and semantic segmentation, can be used to monitor product quality by detecting errors and deviations and making quality predictions. This can lead to more efficient production and reduce the number of rejects. Different algorithms can enhance coatings in real-time by pinpointing defective regions and assisting operators in their analysis in physical industrial products. This can help to improve product quality and reduce waste. (Bastos et al., 2022)

2.3.2 Impact of AI on Various Sectors

AI-based systems have the ability to continuously learn and adjust to changes in accounting practices and new information. As data volumes increase and are processed through software solutions, AI can analyze all the data and identify relevant correlations based on numerous indicators. (Semenova et al., 2023) Institutional advancement can be attained through the enhancement of diverse services. Artificial intelligence applications will significantly improve the quality of educational institutions by helping to assess and enhance university services. (Uluskan M. 2023)

In Yang's study it is proven that the quality of AI services greatly influences the overall experience of collaborating with AI. Additionally, higher AI service quality is linked to better perceived expertise and faster response times. Moreover, the study indicates that the indirect effects of AI service quality on the overall collaboration experience through perceived expertise and response speed are significant. Surprisingly, the fit between AI functions and customer abilities does not significantly impact the relationship between AI service quality and customer response capabilities, such as expertise and response speed. Unexpectedly, it's found that when AI function-customer ability fit is considered, the relationship between AI service quality and the overall collaboration experience with AI is negatively affected. (Yang X. 2023)

Utilizing Artificial Intelligence (AI) solutions within healthcare systems offers organizations a competitive edge in the market, enhancing not only profitability but also the overall well-being of hospitals. By integrating advanced technologies like AI, healthcare ecosystems can strike a balance between delivering high-quality care and managing costs effectively. Moreover, compared to laparoscopic methods, robotic approaches offer advantages such as quicker recovery times, shorter hospital stays, and reduced pain and trauma for patients. (Martins S.M. et al., 2020)

2.3.3 CIM (Computer-Integrated Manufacturing)

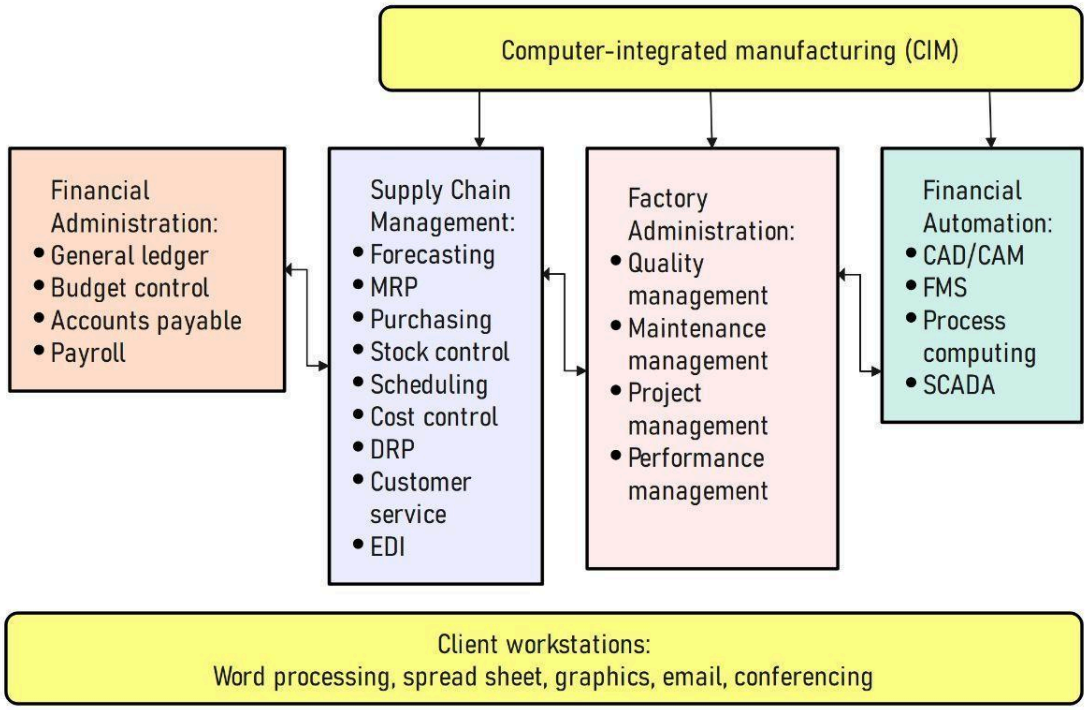

Figure 4: Application software modules (Basu, R. 2023 pp. 107)

Enterprise Resource Planning (ERP) systems serve as integrated IT solutions within organizations, facilitating the exchange of information across various functions. These systems can extend beyond organizational boundaries to encompass the entire supply chain, enabling seamless integration and information sharing. ERP systems consist of multiple modules that can operate independently or interact with one another to support different business functions.

Client workstations typically run PC-based software, a trend that emerged in the late 1980s as manufacturing companies sought comprehensive solutions. Many invested in Computer-Integrated Manufacturing (CIM) systems, albeit with limited success. Adopting an 'open systems' approach for hardware and relational databases enhances

interoperability, allowing different proprietary software packages to interface effectively within a client-server environment. One of the most significant advantages of ERP systems is their ability to provide a holistic, enterprise-wide view of business operations. (Basu, R 2023)

Software testing and Computer-Integrated Manufacturing (CIM) are intricately linked, as CIM systems often rely on software components to control and manage various aspects of manufacturing processes. From a software testing perspective, the implementation of an Internet of Things (IoT) based Computer-Integrated Manufacturing (CIM) system in semiconductor manufacturing involves the integration of Radio Frequency Identification (RFID) technology into the Manufacturing Execution System (MES). This integration is regarded as a significant advancement in manufacturing processes. However, complexities and challenges are introduced, particularly concerning software reliability and functionality. As the CIM system heavily relies on software components to manage and optimize manufacturing operations, rigorous software testing becomes crucial to ensure the system's effectiveness and reliability. Testing methodologies must address various aspects, including RFID data acquisition, system integration, communication protocols, and deep learning algorithms. Thoroughly testing the software components allows manufacturers to mitigate risks, identify potential issues, and ensure seamless integration of IoT technologies into CIM systems, thereby optimizing manufacturing efficiency and productivity. (Chen, Y.-Q., et al 2020)

3 Methodology

3.1 The Survey

The method used in this study consisted of both a survey and interviews. The survey was designed based on the widely recognized SERVQUAL model, developed by Parasuraman, Zeithaml, and Berry (1994). Service quality is widely studied with the help of the SERVQUAL model. The model service quality consists of five dimensions, namely Reliability, Responsiveness, Assurance, Empathy, and Tangibles. Service quality is measured as a difference between service expectations and perceived service (Boakye et al., 2020; Rebualos et al., 2024). The survey included a total of 24 questions, categorized into the aforementioned SERVQUAL dimensions. Additionally, a separate category, 'General,' was included, subdivided into eight specific sub-choices that pertained to broader quality characteristics, allowing for a more comprehensive evaluation of quality factors.

Respondents were required to answer every question in order to complete the survey, ensuring full participation and the collection of consistent data across all respondents. The structure of the survey questions varied: while questions 3 through 24 required numerical responses on a Likert scale, designed to quantify levels of agreement or satisfaction, questions 1 and 2 were open-ended. These open-ended questions allowed respondents to freely express their views, providing qualitative data to complement the numerical insights. This mixed-methods approach enabled a more holistic analysis, capturing both quantitative and qualitative dimensions of service quality.

3.2 The Interview

In addition to the survey, qualitative interviews were conducted to gain deeper insights into the Testing-as-a-Service (TaaS) market situation. Interviews were conducted with two professionals currently working at Fellowmind, a key player in the industry. As noted in academic literature, interviews are a commonly used qualitative research

method, widely applied in studies to gather rich, detailed data. However, as Edwards and Holland (2013) suggest, the familiarity of interviews in everyday life can be both an advantage and a challenge in the research context. On one hand, participants may feel comfortable with the interview format, but on the other, they may enter the process with preconceived notions about how the interview should proceed, which can influence their responses. Therefore, it was crucial for the researcher to establish clear boundaries and expectations, guiding participants to understand the difference between a casual conversation and a structured research interview aimed at gathering specific, relevant data for academic analysis.

The interviews were conducted via Microsoft Teams between August and September 2024. The interview questions were carefully crafted, drawing not only from the literature review but also from the preliminary findings of the survey. This approach ensured that the interviews would complement the survey data, enriching the overall findings of the study. The semi-structured interview format allowed for flexibility in the conversation, enabling interviewees to elaborate on key points while still ensuring that all essential topics were covered.

The survey has been included in the appendices of this study, providing transparency and allowing for a more thorough understanding of the data collection process. The inclusion of this material also allows future researchers to review the methodology in detail, ensuring replicability and the opportunity for further research in this evolving area of study.

4 Results

The survey was conducted using the Typeform application online and distributed via a link through various channels, such as the client company's platforms and LinkedIn. The interviews were conducted using Microsoft Teams and lasted about an hour. Both interviewees were asked the same set of interview questions. The first interviewee, "Expert 1," works at Fellowmind as a Project Manager. The second interviewee, "Expert 2," holds the title of Competence Lead (Advisor) at the same company. Both of them are experienced professionals in the IT field, with expert 2 having particular expertise in testing. The interviews were recorded, transcribed and translated into English for the study.

4.1 The Survey Results

A total of 53 respondents participated in the survey. The results were analyzed using the ANOVA tool, and Tukey's HSD test was applied to explore significant differences identified through ANOVA. While the primary aim of the survey is to assess the TaaS market situation in Finland, responses from other countries have also been analyzed and considered to provide a broader context. The data are presented in a table categorized by country, which includes the country of respondents, number of respondents, and the average and median values per country. The table presents the responses to questions 3 through 24, which required participants to provide a numerical answer by rating the importance of various factors on a scale from 1 to 5, with 1 indicating "Not important at all" and 5 indicating "Extremely important". It should be noted that the majority of respondents originate from Finland, Denmark, or the Netherlands.

Table 1: Country of Respondents, Number of Respondents, Average, and Mean of the Medians per Country

Country	Respondents	Average Score	Mean of the Medians
Finland	19	3.83	4.00
Denmark	14	3.67	3.66
Netherlands	11	3.58	3.69
Germany	4	3.81	3.91
Sweden	2	3.79	3.74
Switzerland	1	4.00	4.10
Thailand	1	3.60	3.48
Poland	1	4.21	4.0

A total of 24 questions were analyzed, and no statistically significant differences were found between countries for most of the questions. However, in question 17, "How important do you consider personal attention from the Testing-as-a-Service provider's employees?", a statistically significant difference was observed.

Based on Tukey's HSD test, the statistically significant differences in the value of personal attention are observed between the following countries for question 17: "How important do you consider personal attention from the Testing-as-a-Service provider's employees?":

Table 2: Statistically Significant Differences Between Surveyed Countries:

Netherlands vs. Germany	Netherlands: 4.00, Germany: 3.50
Netherlands vs. Denmark	Netherlands: 4.00, Denmark: 3.50
Poland vs. Denmark	Poland: 4.00, Denmark: 3.50
Sweden vs. Denmark	Sweden: 3.50, Denmark: 3.50
Germany vs. Switzerland	Germany: 3.50, Switzerland: 5.00
Finland vs. Denmark	Finland: 4.05, Denmark: 3.50
Switzerland vs. Denmark	Switzerland: 5.00, Denmark: 3.50

Switzerland seems to value personal attention the most, but the sample size is very small (only one observation), making the comparison unreliable. Finland and the Netherlands consider personal attention to be important, both averages are higher (4.05 and 4). Germany, Denmark and Sweden seem to value personal attention less compared to other countries, but the differences are not statistically significant.

In the question of Do you use Testing-as-a-Service (TaaS) solutions in your work? The results are as following:

- Finland: Out of 19 respondents, 5 (26%) use TaaS, while 14 (74%) do not. This suggests that while some adoption of TaaS exists, the majority of respondents in Finland still rely on other methods.
- Germany: 2 respondents (50%) use TaaS, and 1 (25%) does not. One respondent (25%) was unsure. This indicates mixed adoption, with a notable level of uncertainty in TaaS usage.
- Denmark: 2 respondents (14%) use TaaS, while the majority, 12 (86%), do not. TaaS usage is relatively low in Denmark compared to other countries.

- Switzerland: The single respondent from Switzerland does not use TaaS, indicating no adoption in this sample.
- Thailand: The single respondent from Thailand uses TaaS, indicating full adoption in this small sample.
- Netherlands: All 11 respondents from the Netherlands do not use TaaS, indicating no adoption in this group.
- Sweden: Both respondents from Sweden do not use TaaS, showing no adoption in this country.
- Poland: The single respondent from Poland does not use TaaS, indicating no adoption in this sample.

Only 18.87% of respondents (10 out of 53) are utilizing TaaS solutions. This indicates that while there is some interest in TaaS, many companies in Finland may still prefer in-house testing or have not fully adopted outsourced testing services. On the other hand, this analysis reveals that TaaS adoption remains inconsistent across countries, with Finland showing the highest usage rate among the surveyed nations, while other countries lag behind. However, the notable small number of respondents from many countries must be taken into account.

4.2 Interview of Expert 1

In the interviews of expert 1, when asking a question of: “What do you think is the current Testing-as-a-Service (TaaS) market situation in Finland?” He described that “The market exhibits a strong demand for diverse client and customer needs. Testing services offer a solution that accommodates even those with limited budgets, making quality assurance accessible without requiring substantial financial commitments. An alternative to not conducting tests exists, though this can lead to compromised quality assurance if adequate support is lacking. This balance provides options ranging from comprehensive testing to more budget-conscious approaches, ensuring a broad accessibility to necessary services. In the next question of “How important do you find

the role of software testing in improving software quality and reliability?" He thought that it's crucial to maintain quality functions throughout the life cycle of a project, not just at the end or during testing phases. If these functions are not properly managed, businesses and public actors alike can experience significant setbacks. Quality assurance starts from the beginning of a project, ensuring that specifications are clear, measurements are accurate, and everything is in place. Additionally, it's important for the process to be adaptive, molding itself to meet the current requirements. This proactive approach helps elevate the overall quality to the necessary standards."

"How important do you consider the following quality dimensions in a Testing-as-a-Service (TaaS) service: Reliability or personal attention?" He answered as follows: "Reliability and other elements are crucial, though it's difficult to rank their importance individually. Instead, the overall integration of these variables is what notably impacts the broader context". The next question: "How important is it for your company to implement quality management practices to enhance overall performance?" He answered: "Quality work is fundamentally initiated by management, which provides both commitment and the authority to operate within an organization. This approach underscores that quality is not the responsibility of a single segment but should permeate the entire organization. It's viewed as a crucial entity that impacts overall performance, emphasizing the importance of a holistic approach to quality management." Follow-up question: What would these quality management practices be? He emphasized the importance of comprehensive quality management frameworks such as EFQM (European Foundation for Quality Management) and Lean, noting their applicability in fostering organizational quality and development. EFQM is highlighted as a versatile tool used for both internal improvements and as a criterion for quality awards within Europe, while Lean, originating from Japan's Toyota production system, focuses on sub-areas like waste elimination and efficiency. The integration of ITIL (Information Technology Infrastructure Library) is also mentioned. He emphasized its role in structuring IT services with specific methods and metrics that enhance agility and customer satisfaction. He underscored the necessity of having a

flexible yet structured approach to quality management, ensuring that quality systems are in place to support organizational and project-specific quality needs. He emphasized that this holistic view highlights the complexity of implementing effective quality management systems that are adaptable yet robust enough to meet diverse organizational demands. It should also be taken into account “Quality Control” and “Quality Assurance”, he said at the end.

In the question of “How important do you find clear and professional communication materials (e.g., reports, documentation)?” Expert 1 highlighted the importance of effective communication in organizational settings, and its important role in conveying facts across various levels. He mentioned that both qualitative and quantitative forms of communication are crucial and they should be able to combine in a certain way. For management, financial metrics like EBITDA are essential, while project managers or team leads might focus on employee satisfaction metrics, underscoring the significance of work satisfaction as a measure of organizational health. The interview also touches on customer satisfaction. He emphasized the necessity of targeted communication in marketing and management, indicating that poorly directed messages can lead to inefficiencies and increased costs. As a summary he stressed that aligning communication with the intended audience and specific organizational goals is vital for effectiveness, particularly in project management and strategic leadership contexts.

“How have cloud services' resources, such as increased computational power and storage, affected the execution of extensive configuration tests and particularly the detection of faults and pruning of configurations in SaaS environments?” His response emphasized the transformative impact of cloud resources, like increased computational power and storage, on scaling and operational efficiency in testing environments. “Utilizing services such as Azure for SaaS applications allows for greater scalability compared to traditional local server setups. The cloud facilitates cost-effective infrastructure management and ensures business continuity, even in scenarios like server failures, by providing geolocation retention and redundancy. This

scalability is crucial for expanding storage effortlessly, unlike the physical constraints and costs of onsite data management. Additionally, cloud environments support more dynamic and flexible configuration for testing, essential in product industries where customization and rapid testing are vital. This adaptability in the cloud significantly enhances the ability to conduct thorough, parameterization, automation, both positive and negative tests, making it a cornerstone of effective product development and service delivery".

Moving to the question of "What do you think are the most important factors to consider when implementing P-TaaS (Performance Testing as a Service) and what are its biggest challenges?" He answered the following: "The complexities of conducting performance tests in SaaS environments, particularly the requirement to obtain specific permissions, which can complicate the process. In Microsoft environments or similar, setting up a test environment comparable to the production setup can be costly. While conducting performance tests in web applications or similar environments might be easier and require fewer permissions, issues like "DDOS protection" must be considered to ensure valid results." He also highlighted that performance testing is not just about the ability to execute tests but also about obtaining reliable results. He also touches on the ease of conducting basic UI performance tests, with the availability of various tools making the process more straightforward. However, "The scope and depth of performance testing can significantly affect its advantages, challenges, and the overall impact on the project."

"How should the scalability and data security challenges of Fuzz testing be solved, and how have API specifications been utilized in this process?" Expert 1 highlighted the challenges and considerations involved in testing within automated and SaaS environments, emphasizing the importance of scalability and security. He also said that auto-scaling should be managed carefully to avoid unnecessary complications. "The principle of least privilege" is crucial in ensuring that the testing environment remains isolated, which not only helps in reducing costs but also secures the testing process, he said. "Specific attention is given to the handling of test data, stressing that it should not

contain real personal information to comply with GDPR and other privacy regulations. Instead, test data should be anonymized to prevent any potential misuse if accessed by unauthorized parties."

Expert 1 also covered the need for permissions, especially in controlled environments like those provided by Microsoft, where any form of penetration or security testing must be pre-approved to avoid legal and ethical issues. He suggested utilizing tools like Swagger for API testing to leverage existing documentation for creating realistic yet secure testing scenarios. "We have a data model documented like that. Let's get it done that way. Injection data for example or something similar.", he stated.

"How do the instances offered by the MTaaS (Mobile Testing as a Service) system, such as server machines, affect the efficiency of testing environments?" Expert 1 discussed his limited experience with real device testing in mobile application testing contexts, specifically mentioning "device farms" where actual hardware is used for testing. He clarified the differences between testing on virtual machines (VMs) and real devices, noting that real devices provide a more realistic testing environment compared to virtual ones, which cannot fully replicate hardware behaviors. The interview also touched on how real devices connected to servers, like those offered by Sauce Labs, allow testers to execute tests that closely mimic real-world operations. Furthermore, Expert 1 highlighted the challenges of testing under different network conditions, such as 2G or no network, which are easier to simulate when using real devices. "If there is only a 2G network available, or even if there is no network available at all, what happens to them? These are good questions, which are easy to test in a way, especially if it's about services with real devices. There you can set up the configurations so that it is possible", he stated.

"What are the special features/quality criteria customers expect that TaaS services should have?" He explained that Fellowmind provides comprehensive services that allow their clients to focus on their core tasks rather than being stuck by testing. Fellowmind offers regular automated testing of their clients' ERP environments to accommodate frequent updates by Microsoft. This regular testing allows the clients'

staff to concentrate on their primary roles, such as billing, rather than being involved in testing every few months. “The expectation from clients is that the tests can be run at any time with any data and remain up-to-date without needing frequent modifications. The metrics for success vary significantly among clients; for some, the absence of failed tests might suffice, while others may focus on the frequency of specific tests failing.” The discussion also touched on the ERP-specific features, where data dependency is critically discussed in terms of how data affects the overall system and reporting is tailored to show test results in different ERP environments, depending on the size and needs of the organization.

“How should the quality of TaaS services be developed?” One significant aspect that expert 1 said is the variability in terminology concerning Testing as a Service (TaaS), particularly between academic and workplace understandings. TaaS is identified as an essential service, yet its definition and application can vary widely. He also highlights the challenges in reporting and usability, noting that enhancing business user engagement with these services is crucial. Currently, “Leapwork” is mentioned as one of the few platforms that allow business users to operate testing tools effectively. The discussion touched on the importance of comprehensive testing for ensuring business continuity, which is largely unaddressed in the market. Additionally, “Security is a major concern, as testing can expose systems or their components to vulnerabilities”. As a summary he highlighted the need for robust, secure, and user-friendly testing services to support business operations effectively.

In response to the final question, “What constitutes a good TaaS service?” He stated that a comprehensive service that addresses the client's needs is essential. He noted that clients often do not know precisely the type of service required. Testing is a specialized field, and many individuals may not fully comprehend their needs beyond basic testing. He emphasized that guidance and strategic direction in testing are frequently absent within organizations, which seek these services to alleviate their operational burdens. The attractiveness of these services increases when they are both

lightweight and cost-effective. “That's why we're looking for that service, so that we can make our own work easier. And especially the lighter the services are.. So, The more attractive they are in a way. Because that price is also more reasonable” he stated. However, he said that is crucial to elucidate the types of testing performed and the methodologies employed. Providing instruction, not merely consulting, is imperative, as many individuals may not grasp the distinctions between functional and non-functional testing. It can be a challenge: “If you talk about functional and non-functional testing, it might be that 80% of the listeners don't necessarily know the difference between them”, he stated. Expert 1 mentioned that understanding the client's context and addressing their knowledge gaps are critical challenges for businesses considering these services: “If we talk directly as if about companies that would like to be included in the service, then those challenges are as they are there in the understanding itself partially. Or just the fact that those things are not known”.

4.3 Interview of Expert 2

When asked, "What do you think about the current state of the Testing-as-a-Service (TaaS) market in Finland?" Expert 2 responded: "I haven’t followed it very closely, but my general impression is that it's not being purchased as much as a service. Many companies seem to prefer keeping it 'in-house' to some extent. The current market/economic situation also affects its broader usage." The next question of “How important do you find the role of software testing in improving software quality and reliability?” she responded: “Extremely important. Having worked in testing for over twenty years and in various projects, it bothers me how little attention it gets in projects. It's often only when we reach the implementation phase that we realize shortcuts were taken in testing. The message I always try to convey in my projects is that testing should be included and considered as early as possible, just as important as any other aspect of project planning.”

In the third question of “How important do you consider the following quality dimensions in a Testing-as-a-Service (TaaS) service: Reliability or personal attention?”

She stated that “Well, if I were to purchase the service, I would absolutely go for it if it's reliable. I would definitely want to see what other primary assignment they've worked on or where else they've provided the service. In other words, I wouldn't buy a "pig in a poke." If a completely new player with no background or reference cases to show up came along, they'd be at a significant disadvantage in the competition, so to speak.” “How important is it for your company to implement quality management practices to enhance overall performance? She stated that “Fortunately, more and more attention is being paid to this issue now. As a company, we're still somewhat in the early stages when it comes to quality management and performance, but as we tackle larger projects and more complex systems, the impact of performance becomes increasingly significant. Luckily, it's something that’s getting more focus all the time”. In the follow-up question: What would these quality management practices be? Expert 2 emphasized performance in mind: “For example, in the one I'm currently working on, several rounds of testing have been done. This has been necessary because the performance hasn't been sufficient, requiring changes to be made. And then, of course, verifying whether those changes have been effective.”

In the question of “How important do you find clear and professional communication materials (e.g., reports, documentation)?” She stated: “It's extremely important. Documentation, in software projects, is often something that gets overlooked, and the effort required for it isn’t always properly accounted for. From a testing perspective, proper documentation is essential for ensuring quality. What constitutes “sufficient” documentation is another matter, but it should at least be clear and at a good standard. It’s difficult to conduct thorough testing if the documentation isn't in order. Reporting, too, is crucial—good reports are straightforward and understandable. Whether it’s a performance report or any kind of tracking report, it should provide a clear overview at a glance. And if further details are needed, one should be able to easily dig deeper into the specifics, especially with reports generated from tools like Jira, which allow for a more detailed examination”.

Moving on to the next question: “How have cloud services' resources, such as increased computational power and storage, affected the execution of extensive configuration tests and particularly the detection of faults and pruning of configurations in SaaS environments?” Expert 2 replied: “What I’ve noticed is when progressing in the project, the testing environments, such as the development environment, tend to have much lower performance compared to production. This is primarily due to efforts to reduce costs. As a result, what often appears in those kinds of tests are erroneous results when the performance limits are reached. However, it has been confirmed and studied multiple times that production has greater capacity, and that it will function properly there. That’s what comes to mind first regarding this issue”.

“What do you think are the most important factors to consider when implementing P-TaaS (Performance Testing as a Service) and what are its biggest challenges?” Expert 2 said the following: “Well, regarding the implementation of performance testing and its challenges, what I generally see is that data, in general, is often the main challenge in many places when it comes to testing. You should have a lot of valid data, especially from a "performance" perspective. That’s the general issue. Usually, data in testing environments is created in an anonymized way, so that’s a challenge. Of course, by copying data from production, you can get valid data, but from a GDPR perspective, that's not always allowed. So, that's clearly one of the challenges—how to tackle this. One approach is to have a method to anonymize the data while ensuring that the quality and integrity of the data remain intact and don't get compromised. In my opinion, that is clearly the biggest problem in terms of performance testing. The most important factor, of course, is that from a business perspective, you’ve considered what the critical aspects of performance testing are, i.e., what needs to be tested? That’s very important. You need to be able to specify what aspects of the system are going to be tested and what goals or results are being targeted.”

“How should the scalability and data security challenges of Fuzz testing be solved, and how have API specifications been utilized in this process?” Expert 2 mentioned that she

has some experience from six years ago but still chose not to answer this question. Also, the question: “How do the instances offered by the MTaaS (Mobile Testing as a Service) system, such as server machines, affect the efficiency of testing environments?” remained unanswered as she did not respond due to her extended period of absence from mobile testing.

“What are the special features/quality criteria customers expect that TaaS services should have?” Expert 2 said that the first thing that came to her mind is, of course, reliability, which is absolutely the most important. “And then, from the client's perspective, the usability of the service is also crucial. It should, in a way, have been somewhat "light," so to speak. Those were probably the most important aspects.” The next question: “How should the quality of TaaS services be developed?” She answered: “Well, the experience I have with them is precisely that data is still a very crucial aspect in testing. What I feel is that data is still in a somewhat weak position in "TaaS" services. In other words, they might not always be able to provide the data needed for testing, and that’s probably the biggest reason why manual testing is often relied upon and done in-house.”

In the final question, “What constitutes a good TaaS service?” Expert 2 stated clearly: “Reliability. And then, of course, it’s important that defects are found. As someone working in testing, I don’t fear bugs being reported; rather, I want the TaaS to reliably identify those defects during the testing phase, so that we don’t end up discovering issues after going into production. Because if that happens, they become expensive to fix.”

5 Conclusions

The analysis of the Survey revealed no statistically significant differences in responses across countries, except in one area: The importance of personal attention from Testing-as-a-Service (TaaS) providers. Respondents from the Netherlands and Finland placed the highest value on personal attention, while those from Denmark and Germany valued it the least. Further analysis using Tukey's HSD test confirmed significant differences between several country pairs, such as the Netherlands and Germany, and Finland and Denmark. This highlights regional differences in how personal attention from service providers is perceived, particularly between countries like the Netherlands and Denmark. However, it is beneficial to take into account the small number of respondents in many of the countries.

Survey results indicate that TaaS adoption remains low across all surveyed countries, with only 18.87% of respondents utilizing TaaS solutions. In Finland, the adoption rate is slightly higher, with 26% of respondents using TaaS, while the majority (74%) do not. This suggests that while some adoption of TaaS exists, many companies in Finland and other regions still favor in-house testing and have not fully embraced outsourced testing services.

The interview conclusions: In the question of "What are the special features/quality criteria customers expect that TaaS services should have?" Expert 2 focuses on the reliability and lightness of TaaS services, while expert 1 emphasizes the continuity of automation, the importance of data and reporting, and the special features of ERP systems. Expert 1 also highlights that the customer expectations are more complex and specific. In the question of “How should the quality of TaaS services be developed”, Expert 2 focuses more on data deficiencies and their effects on the efficiency of the testing process while expert 1 emphasizes user-friendliness, clarity of terminology and data security. In the question of "What constitutes a good TaaS service?" Expert 2’s perspective focuses on the reliability of TaaS services and the detection of errors, while

expert 1 emphasizes more on understanding the customer's needs, the lightness of the service and the importance of instructions.

"What do you think about the current state of the Testing-as-a-Service (TaaS) market in Finland? Expert 2 highlights that TaaS is not widely adopted and that companies prefer to keep testing in-house due to economic constraints and preferences for internal control over testing operations. Expert 1 is more optimistic about the TaaS market, seeing it as responsive to client needs and offering flexible, accessible solutions for businesses with diverse budgets. Expert 1 views the market as having strong demand and offering various options to meet different levels of financial commitment. On the other hand, they both highly value the importance of testing and maintaining quality functions throughout the life cycle of a project. Both expert 1 and expert 2 mention the challenges of performance testing, especially data anonymization and GDPR regulations. It can also be concluded that the demand for TaaS varies in Finland, with the potential for significant demand existing depending on organizational requirements and current economic circumstances. To sum up, it is supposed that the market situation is more positive in Finland than in other countries according to this study.

Since Testing-as-a-Service has not been researched extensively, there are many opportunities for future research, and this applies not only to Finland but to other countries as well. For example, areas such as TaaS market analysis and demand forecasting, customer experiences and satisfaction in TaaS services, or data security and TaaS solutions.

References

Abdolmaleki, M., Mamdoohi, A. R., & Emami, M. (2024). Evaluation of Iran's Rail Freight Transport Efficiency using Data Envelopment Analysis. Civil & Environmental Engineering Faculty, Tarbiat Modares University, Tehran, Iran. Retrieved from [https://www.researchgate.net/profile/Mohammad-Amin-Emami/publication/377564900_Evaluation_of_Iran's_Rail_Freight_Transport_Efficiency_using_Data_Envelopment_Analysis/links/65acb6eff323f74ff1e05e3a/Evaluation-of-Irans-Rail-Freight-Transport-Efficiency-using-Data-Envelopment-Analysis.pdf]. Retrieved 1.4.2024.

Agrawal R., Wankhede V.A., Kumar A., Luthra S. (2023). A systematic and network-based analysis of data-driven quality management in supply chains and proposed future research directions. Emerald Publishing Limited. TQM Journal, 35 (1), pp. 75, Cited 2 times.

Ali, A., Maghawry, H. A., & Badr, N. (2022). Performance testing as a service using cloud computing environment: A survey. Journal of Software: Evolution ..., [PDF] wiley.com. Retrieved from Wiley Online Library. Retrieved 25.3.2024, https://onlinelibrary.wiley.com/doi/epdf/10.1002/smr.2492

Angioni M., Musso F. New perspectives from technology adoption in senior cohousing facilities. (2020) TQM Journal, 32 (4), pp. 771 - 772, Cited 1 times. Emerald Publishing Limited.

Bastos, T. M. da R., Stragevitch, L., & Zanchettin, C. (2022). Visual Analysis of Deep Learning Methods for Industrial Vacuum Metalized Film Product. In Proceedings of the International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (Vol. 4, pp. 380-386). ISSN 21845921. DOI: 10.5220/0010815400003124. Retrieved from Scopus. Type: Conference Paper

Basu, R. (2023). The Green Six Sigma Handbook: A Complete Study for Lean Six Sigma Practitioners and Managers. Routledge. p. 6. Retrieved on 25 February 2024.

Boakye, K. G., Natesan, P., & Prybutok, V. R. (2020). A correlated uniqueness model of service quality measurement among users of cloud-based service platforms. Journal of Retailing and Consumer Services, 55, 102098. https://doi.org/10.1016/j.jretconser.2020.102098

Bono F.M., Radicioni L., Cinquemani S. (2023). A novel approach for quality control of automated production lines working under highly inconsistent conditions. Engineering applications of artificial intelligence 2023-06, pp. 1. Elsevier Ltd.

Chen, Y.-Q., Zhou, B., Zhang, M., & Chen, C.-M. (2020). Using IoT technology for computer-integrated manufacturing systems in the semiconductor industry. Applied Soft Computing, 106065. Elsevier. https://doi.org/10.1016/j.asoc.2020.106065

Chiarini A. (2020), "Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research", The TQM Journal, Vol. 32 No. 4, pp. . https://doi-org.proxy.uwasa.fi/10.1108/TQM-04-2020-0082

Chu, J., Wu, J., Zhu, Q., & Sun, J. (2016). Resource scheduling in a private cloud environment: an efficiency priority perspective. Kybernetes, ISSN: 0368-492X. Retrieved from [https://www-emerald-com.proxy.uwasa.fi/insight/content/doi/10.1108/K-04-2015-0108/full/html#sec006]. Article publication date: 7 November 2016. Publisher: Emerald. Retrieved 1.4.2024

Chuanqi T., & Jerry G. (2017). On building a cloud-based mobile testing infrastructure service system. Journal of Systems and Software, Volume 124, Page 39, ISSN 0164-1212, https://doi.org/10.1016/j.jss.2016.11.016.

Cimini, C., Lagorio, A., Pinto, R., Pezzotta, G., et al. (2023). 5G supporting digital servitization in manufacturing: An exploratory survey. IET Collaborative …. Retrieved from [PDF] [wiley.comFull View](https://ietresearch.onlinelibrary.wiley.com/doi/epdf/10.1049/cim2.12083) Retrieved 1.4.2024.

Dheeraj C., Kalpana S. (2019). ACT Testbot and 4S Quality Metrics in XAAS Framework. International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon). Conference Paper. Publisher: IEEE. Pages 504-505.

Edwards, R., & Holland, J. (2013). What is qualitative interviewing? In G. Crow (Ed.), Research Methods Series. Bloomsbury Academic. Bloomsbury Publishing Plc, 50 Bedford Square, London WC1B 3DP, UK; 1385 Broadway, New York, NY 10018, USA. www.bloomsbury.com. © Rosalind Edwards and Janet Holland, 2013. ISSN: 2048–6812.

Eramo, R., Tucci, M., Di Pompeo, D., Cortellessa, V., Di Marco, A., & Taibi, D. (2024). Architectural support for software performance in continuous software engineering: A systematic mapping study. Journal of Systems.

Fellowmind. (2024). Test automation strategy - The ultimate checklist. [Restricted availability]. Retrieved from an email conversation with a company representative on May 2, 2024.

Fischbach, J., Frattini, J., Vogelsang, A., Mendez, D., Unterkalmsteiner, M., Wehrle, A., Henao, P. R., Yousefi, P., Juricic, T., Radduenz, J., & Wiecher, C. (2023). Automatic creation of acceptance tests by extracting conditionals from requirements: NLP approach and case study. Journal of Systems and Software, 197, 111549. https://doi.org/10.1016/j.jss.2022.111549

Fitzgerald, B., & Stol, K-J. (2017). Continuous software engineering: A roadmap and agenda. Journal of Systems and Software, 123, 176-189. Elsevier.

Francalino, W., Callado, A. D. C., & Jucá, P. M. (2018). Defining and Implementing a Test Automation Strategy in an IT Company. Proceedings of the Euro American Conference on Telematics and Information Systems, 1–5. https://doi.org/10.1145/3293614.3293650

Girardon, G., Costa, V., Machado, R., De Macedo Rodrigues, E., & Neto, A. (2020). Testing as a service (TaaS): A systematic literature map. In Proceedings of the ACM Symposium on Applied Computing (pp. 1989–1996). Retrieved from the ACM Digital Library. Scopus.

Goswami, P., Faujdar, N., Debnath, S., Khan, A. K., & Singh, G. (2024). Investigation on storage level data integrity strategies in cloud computing: classification, security obstructions, challenges and vulnerability. Journal of Cloud Computing, 13(1)

Imran, M., Cortellessa, V., Di Ruscio, D., Rubei, R., & Traini, L. (2024). An Empirical Study on Code Coverage of Performance Testing. Proceedings of the 28th International Conference on Evaluation and Assessment in Software Engineering, 48–57. https://doi.org/10.1145/3661167.3661196

Janani, V., & Krishnamoorty, K. (2015). Cloud testing as a service (CTaaS) – analysis, design and implementation. International Journal of Applied Engineering Research, 10(12), 30393–30406. Scopus. Retrieved 25.3.2024

Juran Institute (2019). Quality 4.0: The Future of Quality? https://www.juran.com/blog/quality-4-0-the-future-of-quality/ Retrieved 26.2.2024.

Karthik, P., & Sekhar, K. (2021). Resource scheduling approach in cloud Testing as a Service using deep reinforcement learning algorithms. CAAI Transactions on Intelligence Technology. John Wiley & Sons Ltd on behalf of The Institution of Engineering and Technology and Chongqing University of Technology. Scopus, 147, 152–153. Retrieved from https://ietresearch.onlinelibrary.wiley.com/doi/epdf/10.1049/cit2.12041

Lim, M. K., Xiong, W., & Wang, C. (2021). Cloud manufacturing architecture: a critical analysis of its development, characteristics and future agenda to support its adoption. Industrial Management & Data Systems, ISSN: 0263-5577. Article publication date: 21 June 2021. Issue publication date: 5 October 2021. Publisher: Emerald.

Luo, Y., Chen, Y., Li, T., Tan, C., & Dou, H. (2024). Cloud-SMPC: two-round multilinear maps secure multiparty computation based on LWE assumption. Journal of Cloud Computing, 13(1), Article number 22. DOI: 10.1186/s13677-023-00586-5. Retrieved from Scopus 24.4.2024

Mahmood, R., Pennington, J., Tsang, D., Tran, T., & Bogle, A. (2022). A framework for automated API fuzzing at enterprise scale. In 2022 IEEE Conference on Software

Testing, Verification and Validation (ICST) Date of conference: 14.4.2022. IEEE. https://ieeexplore.ieee.org/document/9787898

Martins S.M., Ferreira F.A.F., Ferreira J.J.M., Marques C.S.E. An artificial-intelligence-based method for assessing Service quality: insights from the prosthodontics sector (2020) Journal of Service Management, 31 (2), pp. 61, Cited 1 time. Emerald.

Mishra, D., Ostrovska, S., & Hacaloglu, T. (2017). Exploring and expanding students' success in software testing. Information Technology & People, ISSN: 0959-3845. Publisher: Emerald. Article publication date: 6 November 2017.

Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1994). The SERVQUAL 22-Scale Items. Retrieved from ResearchGate.

Poth, A., Werner, M., & Lei, X. (2018). How to Deliver Faster with CI/CD Integrated Testing Services? In Proceedings of the 25th European Conference on Systems, Software and Services Process Improvement, EuroSPI 2018, Bilbao, Spain (pp. 401-409). Communications in Computer and Information Science, Volume 896. Retrieved from Scopus.

Rebualos, R. A., Hidayat, J. J., Redi, A. A. N. P., Rozamuri, A. M., & German, J. D. (2024). Analysis of service quality in engineering design department through SERVQUAL framework. Procedia Computer Science, 234, 1570–1577. https://doi.org/10.1016/j.procs.2024.03.159

Semenova G.N., Mustafin T.A., Telegina Z.A., Bodiako A.V. (2023). Audit of quality management at a smart company: independent expertise vs. artificial intelligence. International Journal for Quality Research, 17 (1), pp. 1-9, Cited 2 times.

Sharma, P., Chetti, P., & Najjar, L. (2022). Testing-as-a-Service (TaaS) – Capabilities and Features for Real-Time Testing in Cloud. International Journal of Computer Science and Information Technology, 14(6). DOI: 10.5121/ijcsit.2022.14603. Retrieved from Researchgate 24.4.2024.

Soundarayaa, R. K., & Balasubramanian, C. (2024). Komodo Mlipir Algorithm-based optimal route determination mechanism for improving Quality of Service in

Vehicular ad hoc network. Journal of Sustainable Computing: Informatics and Systems, Elsevier. DOI: 10.1016/j.suscom.2024.100956

Tamagnan, F., Bouquet, F., Vernotte, A., & Legeard, B. (2023). Regression Test Generation by Usage Coverage Driven Clustering on User Traces. 2023 IEEE International Conference on Software Testing, Verification and Validation Workshops (ICSTW), 82–89. https://doi.org/10.1109/ICSTW58534.2023.00026

Technische Universität Berlin. (2024). What is a Systematic Literature Review? Referred to 26.2.2024. https://www.tu.berlin/en/wm/bibliothek/research-teaching/systematic-literature-reviews/description-of-the-systematic-literature-review-method#:~:text=What%20is%20a%20Systematic%20Literature,about%20the%20question%20under%20consideration.

Ulasien, M. (2023). *Microsoft Azure Fundamentals (AZ-900): Foundational Cloud Concepts*. Pluralsight. Updated March 2024. Retrieved September 10, 2024, from https://app.pluralsight.com/ilx/microsoft-azure-fundamentals-(az-900)-foundational-cloud-concepts/d6896738-3ef4-4deb-b39b-9b7ea414ebf2/59b6cee7-6303-4c00-aa65-1a311c824d57#

Uluskan M. Structural equation modelling – artificial neural network based hybrid approach for assessing quality of university cafeteria Services (2023) TQM Journal, 35 (4), pp. 1067, Cited 1 time. Emerald.

Vijaykumar, S., & Thyagaraj, S. P. (2023). Optimizing multimedia communication in internet of thing network for improving quality of service. Indonesian Journal of Electrical Engineering and Computer Science, 31(2), 1201–1210. DOI: 10.11591/ijeecs.v31.i2.pp1201-1210

Wang, Y., Mäntylä, M. V., Liu, Z., Markkula, J., & Raulamo-jurvanen, P. (2022). Improving test automation maturity: A multivocal literature review. Software Testing, Verification and Reliability, 32(3), e1804. https://doi.org/10.1002/stvr.1804

Wei-Tek, T., & Guanqiu, Q. (2016). Integrated fault detection and test algebra for combinatorial testing in TaaS (Testing-as-a-Service). ScienceDirect. Cited 1 time. Referred to on February 3, 2024.

Werner, S., & Tai, S. (2024). A reference architecture for serverless big data processing. Future Generation Computer Systems, 100. https://doi.org/10.1016/j.future.2024.01.029. Retrieved from ScienceDirect 24.4.2024.

World Economic Forum. (2016, January 14). The Fourth Industrial Revolution: What it means, how to respond. Retrieved from https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ on 26 February 2024.

Yadav N., Shankar R., Singh S.P. Impact of Industry 4.0/ICTs, Lean Six Sigma and quality management systems on organizational performance (2020) TQM Journal, 32 (4), pp. 815 - 835, Cited 1 times. Emerald.

Yang X. The effects of AI Service quality and AI function-customer ability fit on customer's overall co-creation experience (2023). Industrial Management and Data Systems, 123 (6), pp. 1724 - 1726, Cited 1 time. Emerald.

Attachments

Attachment 1. The Survey

TaaS Survey Questions:

1. What is your current country of work?This question is required.
2. Do you use Testing-as-a-Service (TaaS) solutions in your work?This question is required.*
3. Reliability
How important do you find the role of software testing in improving software quality and reliability?
1 = Not important at all
5 = Extremely importantThis question is required.*
4. Reliability
How important do you think it would be for your organization to adopt Testing-as-a-Service (TaaS) to efficiently manage extensive and ever-changing workloads?
1 = Not important at all
5 = Extremely importantThis question is required.*
5. Reliability
How important do you believe it would be for your organization to implement Testing-as-a-Service (TaaS) for efficient resource scheduling to meet quality standards for applications and projects?
1 = Not important at all
5 = Extremely importantThis question is required.*
6. Reliability
How crucial is it for your organization to adopt cloud-based testing for cost savings, flexibility, and efficiency?
1 = Not important at all
5 = Extremely importantThis question is required.*
7.Reliability
How important is it for your organization to select the right testing tool to avoid wasting time and resources?
1 = Not important at all
5 = Extremely importantThis question is required.*
8. Reliability
How important is it for your company to implement quality management practices to enhance overall performance?
1 = Not important at all
5 = Extremely importantThis question is required.*
9. Responsiveness
How crucial is it for your company to consider adopting Testing-as-a-Service (TaaS) to ensure software reliability and quality, especially when operating under tight schedules?
1 = Not important at all
5 = Extremely importantThis question is required.*

10. Responsiveness
How crucial is it for your organization that the quality of AI services influences the overall experience and provides faster response times?
1 = Not important at all
5 = Extremely importantThis question is required.*

11. Assurance
How crucial is it for your company that the TaaS provider uses advanced AI algorithms, to minimize job delays and ensure efficient resource scheduling?
1 = Not important at all
5 = Extremely importantThis question is required.*

12. Assurance
How important is it for your team to have a strong programming background to enhance success in structural and automated testing?
1 = Not important at all
5 = Extremely importantThis question is required.*

13. Assurance
How significant is the investment of time and resources in generating and executing test cases to ensure quality assurance in software development?
1 = Not important at all
5 = Extremely importantThis question is required.*

14. Assurance
How important is it for your organization to use AI-based systems to continuously learn and adapt to changes in accounting practices and new information?
1 = Not important at all
5 = Extremely importantThis question is required.*

15. Assurance
How crucial is it for your team to consider factors like licensing, maintenance, and performance when choosing a testing tool?
1 = Not important at all
5 = Extremely importantThis question is required.*

16. Empathy
How important is it that the Testing-as-a-service provider understands your company's specific needs?
1 = Not important at all
5 = Extremely importantThis question is required.*

17. Empathy
How important do you consider personal attention from the Testing-as-a-service provider's employees?
1 = Not important at all
5 = Extremely importantThis question is required.*

18. Empathy
How important is it that the Testing-as-a-service provider offers tailored solutions?
1 = Not important at all
5 = Extremely importantThis question is required.*

19. Empathy
How important do you find it that the Testing-as-a-service provider's employees show interest in your company's success?
1 = Not important at all
5 = Extremely importantThis question is required.*

20. Tangibles
How important do you consider the modernity of the Testing-as-a-service provider's physical facilities and equipment?
1 = Not important at all
5 = Extremely importantThis question is required.*

21. Tangibles
How important is it that the Testing-as-a-service provider's testing tools and software are modern and efficient?
1 = Not important at all
5 = Extremely importantThis question is required.*

22. Tangibles
How important do you find clear and professional communication materials (e.g., reports, documentation)?
1 = Not important at all
5 = Extremely importantThis question is required.*

23. Tangibles
How important is it that the Testing-as-a-service provider's employees appear professional and well-trained?
1 = Not important at all
5 = Extremely importantThis question is required.*

24. General
How important do you consider the following quality dimensions in a Testing-as-a-Service (TaaS) service?

1 = Not important at all
2 = Slightly important
3 = Moderately important
4 = Very important
5 = Extremely importantThis question is required.*

Performance
Features
Reliability
Conformance
Durability
Serviceability
Aesthetics
Perceived Quality