Master Thesis

Lasting Impacts of COVID-19 on Software Development Projects in Public Sector

for obtaining the academic degree
Master of Science in Engineering

Master's Degree Program Cloud Computing Engineering

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Preface

I am profoundly thankful to my grandparents, parents and my sister, whose support has been my guiding light throughout my academic journey. Their steadfast encouragement and unwavering belief in me have provided the emotional sustenance I needed to navigate the challenges of my studies. Without their love and support, this achievement would not have been possible. To my parents, I owe an immense debt of gratitude for their endless support and encouragement.

Finally, I extend my gratitude to the outstanding faculty at FH-Burgenland, and I want to acknowledge my advisor, Ing. Igor Ivkic, BSc MSc, for creating an enriching educational atmosphere and offering the support essential for my academic and personal development.

I am profoundly grateful and deeply humbled to have had the privilege of undertaking this journey alongside each of you. Your unwavering contributions have not only made this accomplishment achievable but have also imbued it with profound significance. From the depths of my heart, thank you.

Balázs Dékány, BSc

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Abstract

The Corona Virus Disease 2019 (COVID-19) has changed the life on the Earth. COVID-19 has resulted in large amounts of illness and possibly lasting effects on human organization. This time was also extremely challenging in software development projects.

The pandemic has caused unprecedented disruption in the workplace, forcing software development project teams to move to home office and adopt new technologies to support virtual collaboration.

This master's thesis explored the lasting impact of the COVID-19 on public sector software development projects. The purpose of this master's thesis is to investigate how these changes have affected public sector software development projects and to identify the lasting impact of COVID-19 on public sector software development projects. is.

To achieve this, this study used two methods consisting of a systematic literature review and semi-structured expert interviews with selected participants. A systematic literature survey provided a comprehensive overview of existing research on this topic, summarized key findings, and identified knowledge gaps. Expert interviews provided crucial insights into the challenges and adjustments of software projects in the public sector during the pandemic.

The findings showed that the pandemic is having a significant impact on public sector software development projects. Many software development projects were experiencing delays, increased costs, and lost productivity due to the sudden shift to home office and disrupted project schedules. However, the study also revealed some positive effects of the pandemic. This included greater flexibility and agility in project management, improved communication and collaboration, and a renewed focus on the digitalization in the public sector. Overall, this master's thesis provided an overview of the lasting impact of COVID-19 on public sector software development projects. The findings improved our understanding of the pandemic's challenges and impacts, providing insights for future software development in similar disruptions.

Kurzfassung

Die Corona-Virus-Disease 2019 (COVID-19) hat das Leben auf der Welt verändert. COVID-19 hat zu einer großen Anzahl von Erkrankungen und gegebenenfalls zu nachhaltigen Auswirkungen auf die menschliche Organisation geführt. Diese Zeit war auch in Softwareentwicklungsprojekten äußerst herausfordernd.

Die Pandemie hat zu beispiellosen Störungen am Arbeitsplatz geführt und zwang Softwareentwicklungsteams, auf Homeoffice umzusteigen und neue Technologien zu nutzen, um die virtuelle Zusammenarbeit zu unterstützen.

Diese Masterarbeit untersuchte die nachhaltigen Auswirkungen der COVID-19 auf Softwareentwicklungsprojekte im öffentlichen Sektor. Das Ziel dieser Masterarbeit ist es, zu erforschen, wie sich diese Veränderungen auf Softwareentwicklungsprojekte im öffentlichen Sektor ausgewirkt haben. Darüber hinaus wurde es gezielt, die nachhaltigen Auswirkungen der COVID-19-Pandemie auf diese Projekte zu identifizieren.

Um dies zu erreichen, verwendete diese Studie einen Mixed-Methods-Ansatz, der aus einer systematischen Literaturübersicht und semi-strukturierten Experteninterviews bestand. Eine systematische Literaturübersicht bot einen umfassenden Überblick über die bestehende Forschung zu diesem Thema, fasste die wichtigsten Ergebnisse zusammen und identifizierte Wissenslücken. Die Experteninterviews lieferten entscheidende Einblicke in die Herausforderungen und Anpassungen von Softwareprojekten im öffentlichen Sektor während der Pandemie.

Die Ergebnisse zeigten, dass die Pandemie erhebliche Auswirkungen auf Softwareentwicklungsprojekte im öffentlichen Sektor hat. Viele Softwareentwicklungsprojekte erlebten Verzögerungen, erhöhte Kosten und Produktivitätseinbußen aufgrund des plötzlichen Wechsels ins Homeoffice und der gestörten Projektpläne. Die Studie offenbarte jedoch auch einige positive Effekte der Pandemie. Dazu gehörten eine größere Flexibilität und Agilität im Projektmanagement, eine verbesserte Kommunikation und Zusammenarbeit sowie ein erneuter Fokus auf die Digitalisierung im öffentlichen Sektor. Insgesamt bot diese Masterarbeit einen Überblick über die nachhaltigen Auswirkungen von COVID-19 auf Softwareentwicklungsprojekte im öffentlichen Sektor. Die Ergebnisse verbesserten unser Verständnis der Herausforderungen und Auswirkungen der Pandemie und lieferten wertvolle Erkenntnisse für die zukünftige Softwareentwicklung in ähnlichen Krisensituationen.

1   Introduction

The global outbreak of the COVID-19 originating in Wuhan, China in December 2019 caused worldwide disruptions. The spread of the virus has created challenges not only for public health systems, but also for various aspects of society. One area that has been greatly affected is the workplace, with software engineers becoming increasingly important in the development and maintenance of software systems for the sector.

Austria implemented a lockdown on March 16, 2020, which initially forced businesses to quickly shift many employees to home office to reduce disease exposure. Since then, numerous research articles have looked at the obstacles faced by software development projects amid the COVID 19 pandemic. It has highlighted its impact on productivity and efficiency in the industry.

Several research articles have addressed the challenges software development projects face during the COVID-19 pandemic, including its impact on productivity and work-life balance. Although the research focused on the immediate challenges workers face, such as reduced productivity and difficulties in maintaining work-life balance, the lasting impact of COVID-19 on software projects is not yet fully understood.

Within this master's thesis, the underpinning informational framework derives its essence from the examination of the organizational dynamics and operational modalities of a prominent entity operating within the public sector in Vienna, Austria. This organization served as the primary focal point for analysis, offering a rich and nuanced vantage pointed from which to explore the interplay between public sector dynamics, software development projects.

1.1   Problem statement

The global outbreak of COVID-19 has significantly disrupted various sectors, including the workplace, where software engineers play a crucial role in the development and maintenance of software systems. In Austria, the implementation of lockdown measures in March 2020 forced many businesses to transition rapidly to remote work arrangements to mitigate the risk of disease transmission. This shift presented challenges for software development projects, impacting productivity and work-life balance within the industry.

Kettunen et al. (2021) evaluated the impacts of the COVID-19 pandemic on software development in Nordic companies, with a focus on how agility aided in responding to these challenges. The problem statement highlighted the disruptive nature of the pandemic on software development processes and the need for organizations to adapt quickly. It delved into the specific challenges faced by Nordic companies in maintaining productivity and continuity in software development amidst the pandemic-induced restrictions and uncertainties. The authors emphasize the importance of agility as a strategic approach to navigate these challenges effectively.

Neumann et al. (2022) focused how the pandemic has influenced various aspects of agile software development, including team collaboration, communication, project management, and productivity. They aimed to identify the challenges faced by agile teams during the pandemic and explore potential strategies to mitigate these challenges. The study sought to provide insights into adapting agile practices to the changing global landscape and ensuring the continued success of software projects in challenging circumstances.

Da Camara et al. (2020) analyzed the specific challenges faced by agile software startups due to the pandemic, including disruptions to workflows, changes in customer demands, and financial constraints. They sought to uncover the strategies employed by these startups to adapt to the evolving landscape and overcome the obstacles posed by the pandemic. By shedding light on the experiences of agile software startups during the COVID-19 crisis, the study provided insights for startup founders, entrepreneurs, and stakeholders seeking to navigate similar challenges and uncertainties in the industry.

The thematic thread throughout these studies highlights the various impacts of the COVID-19 on software development. While many researchers have explored the challenges faced by workers during the pandemic, the lasting effects of COVID-19 on software projects in the public sector remain unclear. Therefore, the focus of this master's thesis will be on Austrian software development projects in the public sector.

1.2 Research questions

The overall goal of this thesis is to explore the lasting impacts of COVID-19 on software development projects in public sector. To reach this goal, a set of research questions (RQs) have been crafted. These RQs are designed to explore the complexity of the research area, including its multiple dimensions. The following main RQ has been identified:

- **RQ1:** What are the lasting impacts of COVID-19 on software development projects in public sector?

To address the main research question of this thesis, it needs to be broken down into sub-research questions. This approach helps in achieving the overall goal by focusing on specific aspects. It involves examining different time periods to analyze the impact of COVID-19 on public sector software development projects.

- **RQ 1.1:** What was the initial situation of the software projects before the COVID-19 pandemic?

- **RQ 1.2:** How has the pandemic impacted the software projects?

- **RQ 1.3:** What effects are still present today regarding software development projects since the end of the pandemic?

In conclusion, the carefully formulated RQs outlined in this section, directing the investigation and evaluation of the impacts of COVID-19 on software

development projects within the public sector. These research questions were created to explore different aspects of the subject, covering the times before, during, and after COVID-19.

The unique contribution of this research lies in its theoretical, practical, methodological, and policy implications concerning the lasting effects of COVID-19 on software development projects in the public sector. By exploring these impacts, the study aims to provide the challenges faced by public sector organizations, elucidate the changes accelerated by the pandemic.

1.3 Methodological Approach

The primary goal of this thesis is to investigate the long-term impacts of COVID-19 in the selected public organization. To achieve this goal, a Systematic Literature Review (SLR) following Kitchenham and Charters (2007) will be conducted. Based on this, semi-structured interviews will be carried out with 5 experts from the public sector's software projects. The analysis of the interviews will follow Mayring's (2014) methodology.

Systematic Literature Review (SLR):

The SLR by Kitchenham and Charters (2007) is employed to conduct a rigorous evaluation of existing scholarly literature relevant to the research topic. This approach involves a systematic and transparent process of identifying, selecting, appraising, and synthesizing relevant literature to address specific SLR RQs.

The SLR process begins with the articulation of SLR RQs, informed by the objectives of the study. A comprehensive search strategy is then developed, encompassing multiple databases, repositories, and academic journals to ensure the inclusion of relevant literature spanning various disciplines and perspectives.

Next, the scientific papers will be reviewed and filtered using exclusion criteria. Each selected study is critically appraised for its methodological rigor, relevance, and contribution to the research topic, with data extraction conducted to capture insights and findings.

Finally, the synthesized findings from the selected literature are analyzed, interpreted to derive overarching themes pertaining to the lasting impacts of COVID-19 on software development projects in the public sector.

Qualitative Research Method by Mayring:

In conjunction with the SLR methodology, the qualitative research method developed by Mayring (2014) is employed to analyze rich, context-specific insights into the experiences, perspectives, and perceptions of stakeholders within the public sector software development domain. The qualitative research process begins with data collection from interview transcripts. Data collection is then employed to gather firsthand experiences from stakeholders, including IT demand managers, application managers and the CIO.

Data analysis follows the principles of qualitative content analysis outlined by Mayring, involving a systematic process of coding, categorization, and interpretation of qualitative data to identify recurring insights.

Through the integration of these complementary methodologies, this study endeavors to provide a robust, multifaceted examination of the lasting impacts of COVID-19 on software development projects within the public sector.

The literature analysis carried out in this work and the applied qualitative research process attempt to provide a comprehensive understanding the impacts of COVID-19 on software development projects in public sector by using the data collected from expert interviews and analyzed from different perspectives. This master thesis could contribute to understanding the lasting impacts of COVID-19 on public sector software development projects.

1.4 Thesis Structure

This thesis presents the lasting impacts of COVID-19 on software development projects in public sector. Outlined below is the structure of the thesis that guides the subsequent chapters:

- **Chapter 2:** Presents the Related Work in the field and discusses methodologies, approaches for handling COVID-19 on software projects and outline impacts of the pandemic in corporate environment.

- **Chapter 3:** This chapter presents the key definitions and explanations to the thesis, including the terms of pandemic, public sector, and scrum.

- **Chapter 4:** This chapter explains the methods used in the research. It details the theory behind the methodologies that have been employed to highlight the impacts of COVID-19 on software projects in the public sector. The following subchapters are included in this section:

- **Chapter 5** details process of conducting the systematic literature review, provided by Kitchenham and Charters. This includes how relevant literature was selected and analyzed to gather existing knowledge and insights on the impacts of COVID-19 on software development projects in the public sector.

- **Chapter 6** outlines the process of overseeing semi-structured interviews according to Mayring's methodology. This describes creating the interview guidelines, selecting participants, carrying out the interviews, and analyzing the transcripts in MAXQDA.

- **Chapter 7** provides an overview of the key findings. All results are discussed and interpreted in this chapter based on the entirety of the master's thesis.

- **Chapter 8:** In conclusion, this final chapter encapsulates the primary findings and insights gleaned from the research conducted on the lasting impact of the COVID-19 pandemic on public sector software development

projects. It reflects on the contributions made by this thesis to the understanding lasting impacts in the research area. Furthermore, it proposes avenues for future research.

The following figure provides an overview of the master's thesis structure:
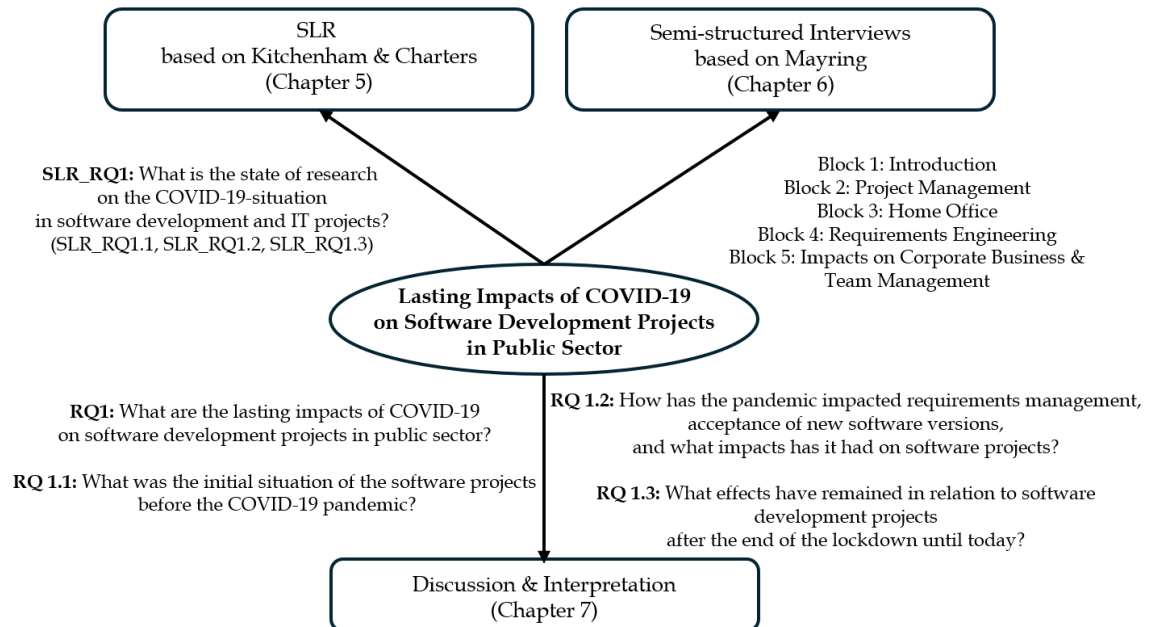

Figure 1: Thesis Structure

2 Related Work

Within this chapter, an exhaustive survey of existing studies and methodologies is presented, all of which have been crafted to tackle the intricate challenges entwined with pandemics and their impact on IT and software development projects. Through a meticulous examination of this rich reservoir of knowledge, our endeavor is to extract invaluable insights while pinpointing gaps that demand attention and that our research is poised to address.

Mousa & Abdelgaffar (2021) investigated challenges of remote work in the public sector during the pandemic, highlighting benefits like flexibility alongside technology, privacy, and communication challenges. Rahman & Farhana (2021) analyzed COVID-19 software projects, noting elevated error rates, particularly in security and performance. Marinho et al. (2021) discussed team behavior changes due to the pandemic, emphasizing adaptation's role in performance. Batra (2020) explored organizational agility's importance, advocating for digital technology investment to enable flexibility.

Nolan et al. (2021) examined remote work's pros and cons among developers, emphasizing the need for infrastructure and support. Marek et al. (2021) studied agile teams' pandemic challenges, noting communication hurdles and adaptation strategies. Ralph et al. (2020) discussed the pandemic's impact on developers, advocating for organizational support and resources. Bao et al. (2022) analyzed developer productivity during the pandemic, noting a decline mitigated by communication tools and clear expectations. This synthesis provides a view of the pandemic's impact on software development, the importance of adaptability, effective communication and ensuring productivity during these unprecedented times.

The subsections will outline the key points relevant to the thesis topic. In 2.1, Previous Studies on Impacts of COVID-19 in Software Projects are explained. In 2.2, Adaptation Challenges are discussed. In 2.3, Factors Influencing Software Development Projects are addressed. In 2.4, the focus is on Software Development in the Public Sector. In 2.5, Resilience Theory is explored. Finally, 2.6 provides a Summary. The following figure summarizes these main topics:
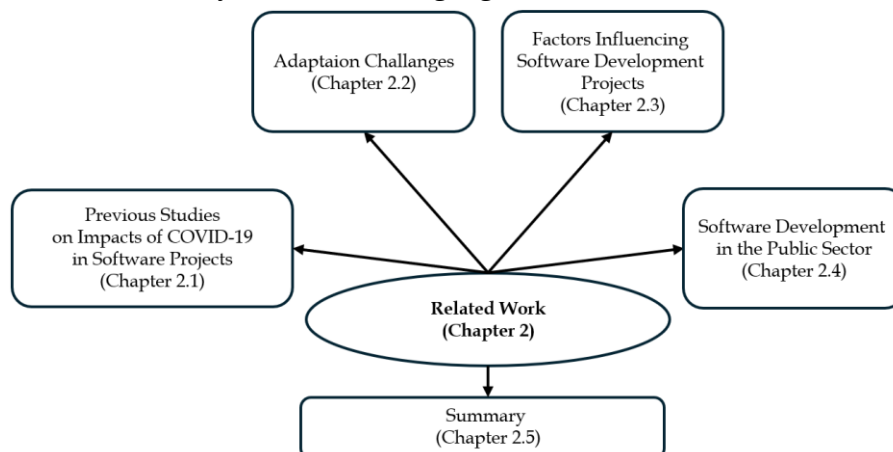

Figure 2: Overview of Chapter 2

2.1 Previous Studies on Impacts of COVID-19 in Software Projects

Neto et al. (2021) provided an in-depth analysis of the impact of COVID-19 on software development. The authors explore various aspects of these effects, offering valuable insights into the topic. Initially, the authors identified the challenges faced by software development projects during the COVID-19 pandemic. These challenges include transitioning to home office, virtual collaboration, and impacts on team productivity. Furthermore, they examined the role of project management methods and tools in addressing the difficulties arising from the pandemic. They discuss how agile methods were adapted to meet the new demands and how the utilization of collaboration tools supported team collaboration.

The authors shed light on the risks associated with the rapid shift to remote work and the potential security vulnerabilities. Additionally, they analyzed the lasting implications of COVID-19 on software development and discuss strategies for addressing these challenges. The authors the importance of flexibility, adaptability, and resilience for successfully executing software development projects during times of crisis.

Mousa, M., & Abdelgaffar, H. A. (2021) argued that while home office has become a necessity in response to the pandemic, it also creates several challenges and barriers to face. The article begins by discussing the benefits of working remotely, such as in-creased flexibility and productivity, and how it has become more common due to the pandemic. However, the authors later identified several challenges when working remotely, such as the need for the right technology and infrastructure, and data privacy and security concerns. As well as the authors also emphasize the importance of effective communication and collaboration in remote work environments, especially in the public sector, where teamwork and collaboration are crucial. They note that working remotely can also create challenges for managers and executives who need to ensure that employees are productive and achieve their goals.

The study conducted by Azeem et al. (2022) investigated the impacts of the COVID-19 pandemic on risks encountered by infrastructure projects. The research delves into the multifaceted ramifications of the pandemic on infrastructure development endeavors within the Pakistani context. Through a systematic exploration of empirical data and theoretical frameworks, the study sheds light on the disruptions, challenges, and vulnerabilities introduced by the pandemic across various facets of infrastructure projects. From supply chain disruptions to labor shortages and regulatory uncertainties, the research elucidates the intricate interplay between the pandemic-induced disruptions and the risk landscape of infrastructure projects in Pakistan.

Rahman, A. A. U., & Farhana, E. (2021) investigated the presence of bugs or errors in software projects created for COVID-19 related needs. The study analyzed 30

open-source software pro-jects developed on various platforms such as GitHub and GitLab. The authors used various bug tracking and analysis tools to identify and categorize the defects found in the projects. The results of the study show that software projects related to COVID-19 have a higher error density than the average density seen in other software projects. The study also found that most of the bugs were related to security and performance issues. The researchers conclude that the increased pressure to develop software projects in response to the pandemic may have led to an increase in bugs. The study recommends that developers prioritize testing and debugging during software development to minimize the occurrence of bugs, especially in the context of important and urgent projects such as project related projects. regarding COVID-19.

Batra, D. (2020) explored the impact of the COVID-19 pandemic on the effectiveness of information and organizational systems. The article argued that the pandemic has highlighted the importance of organizational flexibility and the need for organizations to adapt quickly to changing circumstances. The researcher provided an overview of organizational agility and the role of information systems in enhancing it. The discussion then shifts to how the pandemic has impacted organizational agility, including changes in working patterns, supply chain disruptions, and higher demand for workers.

Marinho, M. et al. (2021) discuss the impact of the COVID-19 pandemic on the behavior and performance of development teams. The study analyzed the results of an online survey of 81 developers in Brazil. Research shows that the pandemic has had a significant impact on the behavior of development teams, including increasing stress and workload, changing communication patterns, and moving to remote work. The researchers also found that teams that were able to adapt and maintain positive team behavior during the pandemic were more likely to perform better and be more satisfied with their jobs. Furthermore, the study highlights the importance of effective communication, mutual support, and cooperation in maintaining positive team behavior during a pandemic. Marinho, M. et al. recommend that development teams prioritize building strong momentum and team support to overcome the challenges of the pandemic and achieve better performance.

The key themes addressed by Bezerra et al. (2020) include human and organizational factors and productivity in remote work. The study delves into the influence of human factors, particularly the effects of the pandemic on the well-being and workload of team members, and investigates how elements like stress, and adaptation to the altered work environment shape productivity. Furthermore, the research explores organizational factors, with aspects such as leadership dynamics, resource allocation, and company support, and seeks to understand how these organizational determinants impact team performance. The researcher analyzed the challenges and benefits associated with remote work arrangements during the pandemic. They also explored how factors such as

communication, collaboration tools, and work-life balance affect the productivity of software teams operating remotely.

2.2 Adaptation Challenges

The COVID-19 has introduced challenges for software development projects, particularly within the public sector. Organizations have had to rapidly adapt to new ways of working while also grappling with significant disruptions to global supply chains. These dual pressures have forced teams to rethink their traditional practices and find innovations to maintain productivity and project timelines.

Adaptation challenges primarily stem from the shift to work in home office, which introduced complexities in collaboration, communication, and productivity. Teams are now more reliant on digital tools and technologies to coordinate efforts and ensure project continuity.

During COVID-19 phase, there has been a notable shift to work in home office, prompting software development teams to navigate new challenges in collaboration, communication, and productivity. Lee, H. (2021) focused on understanding the shifts in workplace practices prompted by the pandemic. The author delves into the factors influencing these changes, particularly the roles of organizational support. Emotion plays a significant role in how individuals respond to changes in their work environment. Organizational support, including communication, resources, and policies, plays a vital role in facilitating smooth transitions and ensuring employee well-being during times of change.

Home Office:

Kniffin et al. (2021) examined the implications of COVID-19 on work practices, shedding light on the challenges and opportunities faced by organizations amidst the pandemic. The sudden onset of the COVID-19 required a rapid transition to work from home for many employees, fundamentally altering traditional work practices and dynamics. This shift has introduced implications for productivity, collaboration, and employee well-being. Organizations have had to adapt their work practices to accommodate remote work arrangements, implementing new technologies and communication platforms to facilitate virtual collaboration. However, the remote work paradigm has also brought to the forefront issues related to work-life balance, employee engagement, and social isolation, impacting individual and organizational outcomes. Furthermore, the study highlights the need for organizations to revisit their policies and practices regarding remote work.

Agile Methodology:

Choudhary and Rakesh (2016) propose an approach that utilizes agile methodology for software development, aiming to enhance project efficiency and adaptability. The Agile methodology, characterized by iterative and incremental development, emphasizes collaboration, flexibility, and customer feedback throughout the development process. The authors highlight the benefits of Agile,

such as increased customer satisfaction, and faster delivery-Their approach advocates for breaking down the development process into smaller, manageable iterations. The authors emphasized the importance of stakeholder involvement, promoting transparency and alignment of project goals.

Asynchronous Communication:

Wang, Y., & Shepherd, J. (2021) explore various forms of asynchronous communication, such as email, project management tools, and messaging platforms, and their impact on team collaboration and productivity. Through empirical data and insights gathered from the case study, the authors provide valuable findings on the role of asynchronous communication in overcoming challenges associated with distributed agile development. They highlight the advantages of asynchronous communication, including flexibility in time management, enhanced focus on tasks.

Task Management Systems:

The importance of task management systems such as Jira is highlighted by Mak, D. K., & Kruchten, P. B. (2006) in streamlining project workflows, enhancing team collaboration, and ensuring transparency in task allocation and progress tracking. Through empirical analysis and case studies, the authors provide insights into the challenges and opportunities associated with task coordination in distributed agile environments. They discuss how task management systems enable teams to overcome barriers posed by distance and time zone differences, thus enabling seamless collaboration and communication. Additionally, the paper underscores the significance of integrating task management systems with agile methodologies to optimize project management processes and improve overall team performance.

2.3   Factors Influencing Software Development Projects

In the software projects, many factors interplay to shape their trajectory and outcomes. Understanding these factors is paramount for effectively navigating the complexities inherent in such endeavors. This section delves into the multifaceted realm of factors influencing software development projects, exploring both internal and external dimensions. By dissecting these influences, the aim is to unravel their intricate dynamics.

Embarking on this exploration, the focus initially lies on examining the internal factors that exert a significant influence on software development projects. (2.3.1 Internal Factors) These factors emanate from within the organizational realm and encompass aspects such as team dynamics, organizational culture, and resource allocation strategies. By scrutinizing these internal dynamics, insights are sought into their impact on project execution and outcomes.

Subsequently, attention turns to external factors (2.3.2 External Factors) that exert their influence on software development projects from beyond the organizational boundaries. These factors encompass a broad spectrum of influences, ranging

from market dynamics and regulatory frameworks to technological advancements and socio-economic trends. Through a meticulous examination of these external forces, efforts are made to uncover their implications for project planning, execution, and adaptability. By dissecting both internal and external factors, this section provided an understanding of the intricate interplay shaping software development projects.

2.3.1 Internal Factors

Within the realm of software development projects internal factors encompass various aspects inherent to the organization itself, including resources, technology choices, and project management methodologies. Understanding the nuances of these internal dynamics is essential for effectively managing and steering software development projects towards favorable outcomes.

In this section, the internal factors are explored, with each component dissected to unravel its significance and impact on project execution. By examining the allocation and utilization of resources, the selection of appropriate technologies, the composition and dynamics of project teams, and the adoption of project management methodologies, insights are sought into how these factors influence the trajectory and outcomes of software development projects. Through a comprehensive exploration of internal factors, light is shed on their dynamics and implications for project success.

Resource allocation:

Park et al. (2015) explored the complexities of resource allocation in software projects, considering practical considerations. The authors highlight the importance of effectively allocating human resources to meet project requirements while considering factors such as skill levels, availability, and task dependencies. They propose a novel approach that integrates qualitative and quantitative factors to facilitate more informed decision-making in resource allocation processes. This approach involves identifying key project tasks, assessing the skills required for each task, and matching them with available resources based on competency levels and availability. Additionally, the authors emphasize the significance of dynamic resource allocation strategies that can adapt to changing project needs and resource constraints over time.

Succes factors influencing software development projects:

Kamal, M. M. (2006) discusses critical success factors (CSFs) influencing IT innovation adoption in the government sector, which can also be relevant to software development projects. Some of the CSFs identified in the study that may apply to software development projects include:

- **Top Management Support**: The active support and involvement of top management are crucial for the successful adoption of IT innovations. This support ensures that necessary resources are allocated, strategic decisions are made, and organizational goals are aligned with the IT project objectives.

- **Stakeholder Engagement**: Engaging relevant stakeholders throughout the project lifecycle is essential for gathering input, addressing concerns, and fostering a sense of ownership and acceptance. Stakeholder involvement ensures that the software solution meets user requirements and aligns with organizational goals.

- **Effective Communication**: Clear, consistent, and open communication among all stakeholders is necessary to facilitate understanding, address concerns promptly, and maintain alignment with project goals. Effective communication channels ensure that project information is shared transparently, and that feedback is solicited and acted upon.

- **Technical Support and Infrastructure**: Adequate technical support and a reliable infrastructure are essential for supporting the software solution and addressing any technical issues that may arise during the project. Technical support ensures the smooth operation of the software system and minimizes downtime.

The importance of top management support cannot be overstated in project success, as it facilitates the provision of resources, strategic decision-making, and alignment with organizational objectives. Effective communication is indispensable for fostering understanding, addressing concerns, and maintaining coherence across project stakeholders. While project managers are integral to project success, it is essential to recognize that they do not possess supernatural abilities; rather, their expertise and experience are significant for risk management and project oversight. Furthermore, monitoring and evaluation serve as indispensable tools for gauging project progress, identifying improvement areas, and safeguarding the attainment of project objectives.

2.3.2   External Factors

In the landscape of software development projects, external factors exert a significant influence on the trajectory and outcomes of endeavors. These external factors encompass a wide array of influences stemming from the political, economic, societal, and technological domains. Understanding the impact of these external dynamics is crucial as they can affect project goals, schedule, and budget, thereby shaping the overall success of software development initiatives. This section delves into the realm of external factors, aiming to dissect the diverse influences that emanate from beyond the organizational boundaries. By examining political shifts, economic trends, societal developments, and technological advancements, insights are sought into how these external forces impact software development projects.

Huberts, P. et al. (2017) discussed several external factors that significantly impact software development projects in the public sector. They identify key factors such as regulatory requirements, political influences, economic conditions, and technological advancements:

- **Regulatory requirements** are highlighted as crucial external factors, as public sector projects must adhere to specific laws, standards, and policies that govern data security, privacy, and accessibility. These regulations can affect project timelines, costs, and design choices.

- **Political influences** are also significant, with government policies and priorities directly impacting project funding, scope, and strategic direction. Changes in political leadership or policy can lead to shifts in project objectives or the reallocation of resources.

- **Economic conditions** determine the availability of financial resources for public sector projects. Economic downturns or budget constraints can result in reduced funding, which may necessitate project delays, scaling down of project scope, or prioritization of certain functionalities.

- **Technological advancements** are another external factor, with rapid changes in technology influencing the tools, platforms, and methodologies used in software development. Staying current with technological trends is essential for ensuring that public sector projects remain relevant and effective.

2.3.3 Summary

Internal factors are pivotal in encompassing resources, technology choices, team composition, and project management methodologies. Understanding these dynamics is essential for effectively managing projects towards favorable outcomes. Effective resource allocation, as discussed by Park et al. (2015), emphasized the importance of considering skill levels, availability, and task dependencies to improve project performance. Kamal (2006) highlighted critical success factors such as top management support, stakeholder engagement, effective communication, project management competence, change management, technical support, and continuous monitoring and evaluation.

External factors also significantly influence the success of software development projects, particularly in the public sector. These include political, economic, societal, and technological influences that shape project goals, schedules, and budgets. Huberts et al. (2017) identified key external factors such political influences, economic conditions, and technological advancements. Regulatory requirements mandate compliance with laws and policies governing data security, privacy, and accessibility, impacting timelines, costs, and design choices. Political influences affect funding, scope, and strategic direction, with changes in leadership potentially shifting project objectives. Economic conditions determine financial resource availability, with downturns leading to reduced funding and possible project delays or scope reductions. Technological

advancements necessitate staying current with trends to ensure project relevance and effectiveness. Understanding and managing these external factors are essential for the successful execution of software development initiatives in the public sector.

2.4   Software Development in the Public Sector

As governments worldwide increasingly embrace digital transformation, the importance of robust software solutions tailored to meet the unique needs of public administration has become more apparent. In this section, we delve into stakeholder engagement and transparency exploring its distinct characteristics. We aim to get an understanding of these entities, that navigate the complexities of technology adoption, project management, and stakeholder engagement. The key points of the subsections are summarized in the following figure:
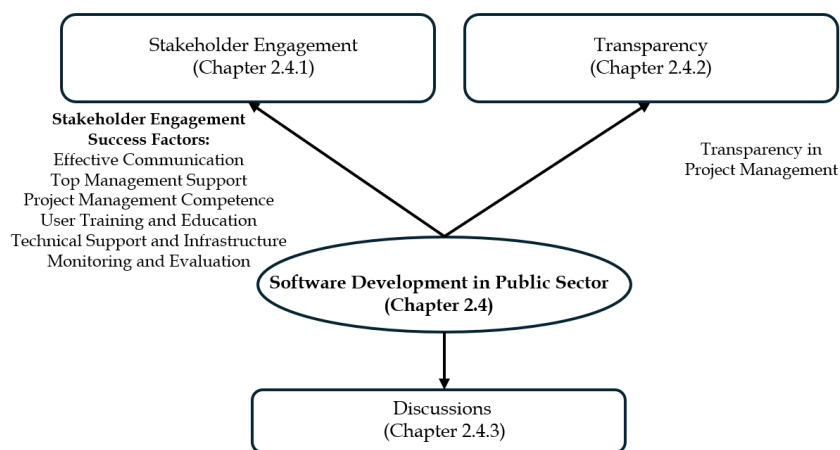
Figure 2: Overview of Chapter 2.4

2.4.1   Stakeholder Engagement

Engaging various stakeholders and ensuring transparency and accountability are crucial concerns in public administration. In the realm of software development within the public sector, these considerations take on heightened significance. As government entities endeavor to deliver effective and efficient digital solutions, the involvement of diverse stakeholders, including policymakers, citizens, and civil society organizations, becomes imperative. Transparency in decision-making processes, project management, and resource allocation is essential to foster trust and confidence among stakeholders and the public at large. In this section, we explore the principles and practices of stakeholder engagement and transparency in software development projects in the public sector. By examining strategies for effective engagement, mechanisms for promoting transparency, and the role of technology in enhancing accountability, we aim to elucidate how these factors influence the outcomes and sustainability of software initiatives in governmental organizations.

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Stakeholder Engagement:

According to Bryson, J. M., & Crosby, B. C. (1992), stakeholder engagement refered to the active involvement and collaboration of various stakeholders in addressing public problems and challenges within a shared-power environment. This involvement entails the participation of diverse stakeholders, including citizens, community groups, governmental agencies, and other relevant parties, in decision-making processes and actions aimed at promoting the common good and achieving collective goals.

Pandey and Gupta (2017) write about stakeholder engagement as the process of involving relevant stakeholders actively in the planning, decision-making, and implementation phases of a project. This engagement is critical for aligning the diverse interests of various stakeholders, fostering collaboration, and ensuring transparent communication. In the context of Government-to-Government (G2G) e-government projects, stakeholder engagement aims to address and reconcile the differing priorities and expectations of multiple government agencies and other involved parties.

In the context of G2G e-government projects, stakeholder engagement stands as a cornerstone. These projects often involve multiple government agencies, each with its own priorities and expectations. Effective stakeholder engagement helps address and reconcile these differing priorities, facilitating smoother project execution and mitigating potential impasses.

Stakeholder engagement success factors:

Ahmed, Kumar, and Kumar (2018) identified several critical success factors for information systems implementation. These include following success factors:

Effective Communication: Ensuring clear, consistent, and open channels of communication among all stakeholders to facilitate understanding and address concerns promptly.

Top Management Support: Securing the commitment and active involvement of top management to provide necessary resources, make strategic decisions, and support project initiatives.

Project Management Competence: Having skilled and experienced project managers who can plan, execute, and monitor project activities effectively while managing risks and ensuring project alignment with goals.

User Training and Education: Providing comprehensive training and educational programs to ensure that users are well-equipped to utilize the new system efficiently and effectively.

Technical Support and Infrastructure: Ensuring that there is adequate technical support and a reliable infrastructure in place to support the new system and address any technical issues that may arise.

Monitoring and Evaluation: Continuously monitoring the project's progress and evaluating its outcomes to ensure that it meets its objectives and delivers the expected benefits.

2.4.2　　Transparency

According to Jashari and Pepaj (2018) transparency can be defined as the principle that requires public institutions to provide accessible, clear, and timely information about their activities, decisions, and performance to the public. This transparency facilitates public oversight and understanding of governmental processes, fosters accountability among public officials, and enhances public trust in government institutions.

However, transparency allows open access to the development process for peer reviews and external feedback. This can lead to higher quality software as bugs and issues can be identified and addressed by a wider audience.

It also encourages collaboration not only within the development team but also with other governmental and private sector partners.

Transparency in Project Management:

Transparency in project management involves the open and clear communication of project information among all stakeholders. This includes sharing progress updates, and decision-making processes. Transparency aims to build trust, foster collaboration, and ensure that everyone involved in the project is well-informed and aligned with the project's goals and objectives. In the agile project management, transparency is particularly emphasized through stand-up meetings, visible project boards, and feedback loops, which help maintain an ongoing flow of information and promote a culture of openness and accountability. (Betta and Boronina, 2018)

2.5　Summary

The related work of the master's thesis analyzed several points connected with the management of risks in software development, concerning pandemic situation, additional challenges of COVID-19, and public sector. Therefore, from the reviewed literature, distinct factors and approaches are presented that may affect project success and sustainability. This section examined how the COVID-19 pandemic affected software development practices, including remote work, collaboration platforms, agile methods, asynchronous communication, and task management tools. Similarly, Lee (2021), Kniffin et al. (2021), Choudhary and Rakesh (2016), Wang and Shepherd (2021), and Mak and Kruchten (2006) stressed the necessity for organizational transformation to adopt remote workspaces and the use of efficient tools to sustain the corporate flow.

Several internal factors to the software development projects including resource management, team issues, and management of the process are clearly addressed. Hsu et al. (2013), Alshare et al. (2013), and Gupta et al. (2011) also highlighted the

importance of the factors to meet project objectives and stakeholders needs. The external environment is seen to be a key factor that affects projects, especially those that are in the public domain. Huberts et al. (2017) highlighted how politics can affect project goals and results, economic constraints can impact delivery, societal factors influence projects and their success, and technology affects project outcomes, emphasizing the need for flexibility and adherence to legal constraints.

Software development in operation is discussed basing on the engagement of stakeholders in the public sector as well as practicing radical openness and communication. Pandey and Gupta (2017) emphasize the discussions with stakeholders and clients in agile development settings to achieve user-oriented outcomes and successful project implementation with the help of stakeholders' support and contributions.

3 Theoretical Background

This chapter offers a theoretical overview for the research topic of this master thesis. It opens with the definition of pandemic in Austria, and COVID-19. After that, the chapter continues by considering public sector, and software development in public sector. Next, software development methodologies such as Agile and Scrum will be discussed. The following graphic provides an overview of these topics:
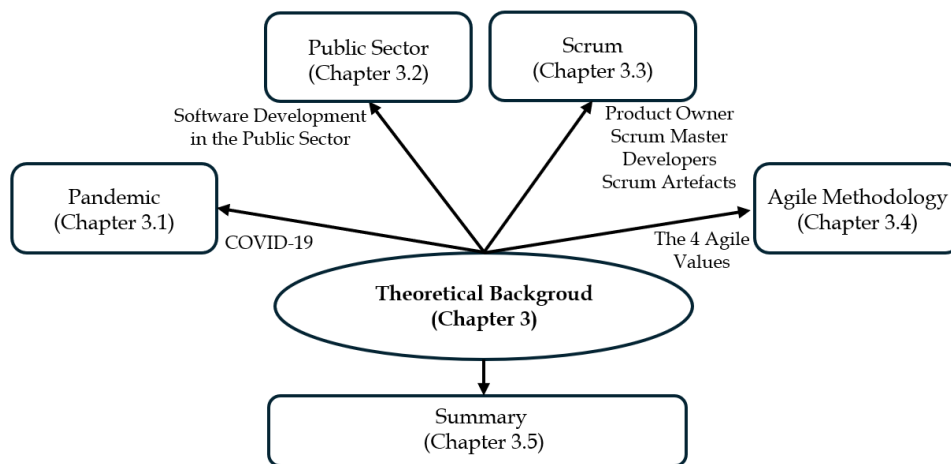

Figure 4: Overview of Chapter 3

3.1 Pandemic

One of the primary elements of the COVID-19 was the surge globally of a crisis that appeared late in the year 2019 and its immoderate nature necessitated quick reactions from both public and private sectors. This part is provisioned with a meticulous explanation of "pandemic", it lays a solid basis for the one to go into the depth of the question and the lingering impacts on public-sector software development projects. Innovation during project execution requires corporate actors to be flexible to the acceleration of technology-dependent business processes during COVID-19 in Austrian public sector in 2020.

In the software development projects, a pandemic introduces unique challenges and necessitates rapid adaptation to new working conditions (Chapter 2.2). The sudden shift to remote work, changes in project priorities, and increased demand for digital solutions require software development teams to be agile and responsive. Public-sector projects, in particular, face added pressures to maintain essential services and ensure accessibility for all citizens. Understanding the dynamics of a pandemic is essential for developing strategies that allow software development projects to continue effectively and efficiently, despite the disruptions caused by such global health crises.

COVID-19:

COVID-19 or "Coronavirus Disease 2019" was first recognized in December 2019 in Wuhan, China. The infectious disease which was caused by the novel coronavirus SARS-CoV-2 quickly spread to countries all over the world eventually becoming a global pandemic.

The impact of COVID-19 on health has been massive and systemic affecting not only other aspects like economies but also software development projects. All countries over the globe have taken into lockdowns among others so as to control its spread and minimize its consequences. Understanding the nature of COVID-19 will help design effective containment strategies and reduce its implications on society on one hand while positioning it better for another wave.

3.2 Public Sector

A segment of the economy which is entirely governmental and provides the public with public goods and services is known as the "public sector". Examples of these organizations include health services, schools, and highways. These are the business lines that corporate organizations can provide and owning. Over and above the above, transportation, public safety, social welfare, and infrastructure development are among the services. On the other hand, the public sector is financed through taxes and public revenues, and its core goal is to enhance the well-being and interests of the general public as a whole rather than necessarily making private profits for private interests. Some elements that make the public sector different from the others are the need for the public to be held accountable and transparent and obey the rules and orders that are made by the government. (Dippelsman, R. J. et al., 2012)

Software Development in the Public Sector:

Software development in public sector encloses the entire life cycle such as software creation, testing, deployment and maintenance of software dedicated software made for dealing with specific business operations and governmental and public organizations implementation and regulatory demands.

The software that is thus constructed is often bundled with modules or add-ons that allow the user to program more efficiently, extend the service delivery process, and help the organization achieve proper performance. IT projects could consist of developing fresh software codes, the amendment of software that already exists, or the integration of various existing systems to make operations more streamlined and environmental data more transparent.

Consequently, there are several software development issues targeted at governmental record-keeping rules and security requirements, as well as possibilities for diverse group accessibility and usability, and the handling of digital transmissions. (Borg, M. et al., 2020).

3.3 Scrum

Scrum, a Minimal Framework, is used to generate value by combining the most important and available knowledge to the entire team and by usage of simple techniques by the team to create a shared goal. The core practices of Scrum include the use of metrics and formal models to monitor progress and diagnose accuracy, and this is one of the important steps in the journey towards correct project management practices. Scrum stipulates the main three roles: the product owner who outlines the work through the product backlog. The team certified by Scrum, which developers decide on a selected job to turn to a potentially releasable increment during a very limited sprint time. The Scrum Master, who gets the team to complete their work properly. The majority purpose behind Scrum is that it is the minimal one that is achieved by only defining the elements for its Scrum Theory to be executed. By the decisions they make, the experts show the team through the scoreboard who is doing better than others, making the process of change visible, and thus by understanding this, they make the necessary steps to improve. (Schwaber, K., & Sutherland, J., 2020)
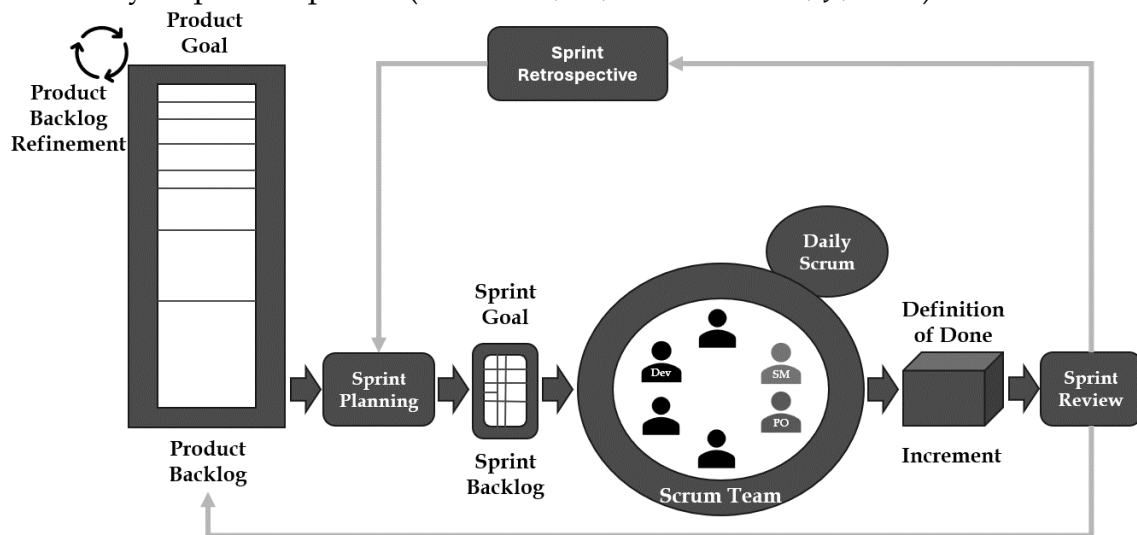
Figure 5: Scrum Framework

3.4 Agile Methodology

The principles of Agile in the Agile Software Development Manifesto, centered in the flexible and iterative software development process, are definite emphases. Agile Methodology, as accepted by the Agile Software Development Manifesto, is an iterative approach to software development that prioritizes (Butt, S. A. et al., 2021):

- Prioritizing people and their interactions over rigid processes and tools,
- Focusing on functional software rather than extensive documentation,
- Emphasizing collaboration with customers over negotiating strict contracts,
- Adapting to changes instead of strictly adhering to predetermined plans.

Agile methodologies promote adaptive planning, evolutionary development, early delivery of software, and continuous improvement, aiming to deliver value to customers more effectively and efficiently compared to traditional methods (Agile Alliance, 2001).

Figure 6: The 4 Agile Values (according to Hygger, 2024)

3.5 Summary

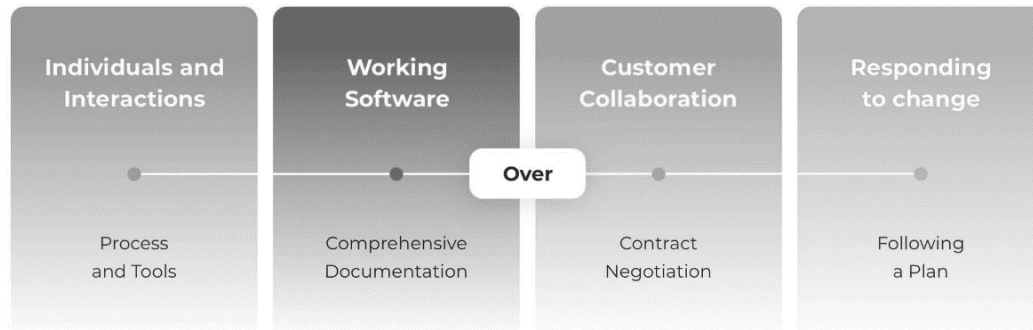This chapter provided the theoretical background for examining the enduring implications of COVID-19 on software development projects within the public sector. It begins by discussing aspects of software development and external factors influencing software projects. The chapter then delved into the impacts of the pandemic on software development practices and project management strategies, offering theoretical perspectives on its long-term consequences.

It explained what is meant by a pandemic including its global nature and how it disrupts social norms, economies, health systems among others worldwide. Towards the end of 2019, COVID-19 was discovered resulting into a worldwide crisis that required quick interventions from both public and private sectors. This section provided a firm foundation for comprehending the tremendous implications of the disease for government's soft projects thus stressing need for agility given their accelerated push towards new technology.

The conversation shows how pandemics like COVID-19 pose specific problems for software development projects. There is a need for rapid adjustment to new operating systems caused by the worldwide outbreak like remote work and increased demand for digital solutions. In public projects have an added burden of maintaining essential services without bringing about disparities in access under changing situations.

There is also a contextualization of the role of the public sector in supplying essential goods and services, which showcases its accountability to the public and dependence on government finance that it entails. This field's software development activities cover full life cycles regarding specific regulatory requirements as well as by means of integrating software solutions through streamlined software development.

The underpinning theories discussed here also inform agile methodologies (e.g., Scrum and Agile Methodology) by embracing iterative, collaborative approaches to software development. Moreover, these approaches emphasize adaptability, adaptable planning and constant improvement making them useful for navigating disruptions to provide value in a post-pandemic world.

To conclude, this chapter lays down the theoretical background necessary for investigating long-term impacts of COVID-19 on public sector software development projects. The chapter provides insights about key definitions of the pandemic, technological accelerations and adaptive strategies thereby equipping stakeholders with knowledge needed to instill resilience and innovation.

4 Methodology

In this section, the methodology employed to investigate the lasting impacts of the COVID-19 pandemic on software development projects in the public sector will be detailed. The primary motivation behind this study is to comprehensively understand the effects of COVID-19 on software development projects, with the overarching objective of identifying specific impacts and developing interview questions for further exploration with professionals working in the department "Digital" of a leading organization within the public sector in Vienna, Austria.

4.1 Motivation & Objectives

The motivation for this study is to explore the enduring effects of the COVID-19 pandemic on software development projects within the public sector. The study has two main objectives. First, to recognize the specific impacts of COVID-19 on software projects. Second, to develop topics for interviews based on these impacts for exploration with five professionals in public sector.

4.2 Research and Evaluation Process
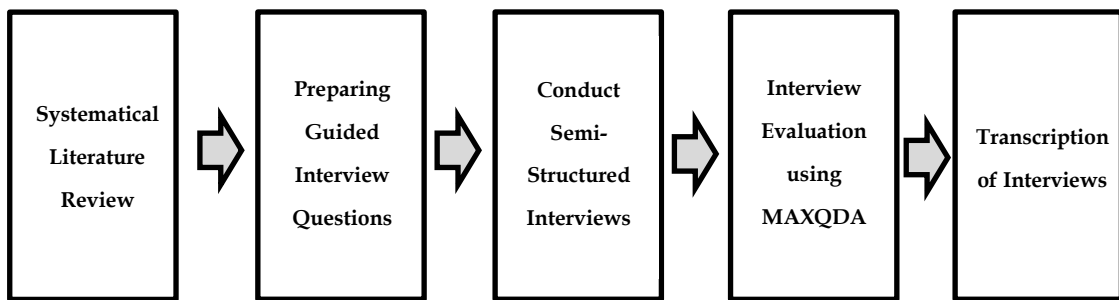
Figure 7: Process for Mix-Methodology Research

The methodology adopted for this study involves a multi-phase approach, beginning with a systematic literature review (SLR) followed by semi-structured interviews. The SLR aims to comprehensively explore existing literature to uncover insights of COVID-19 in software development projects. After conducting a structured analysis of existing literature, thematic input for semi-structured interviews must be developed to capture relevant information. It involves identifying and integrating common themes from the literature, organizing them into coherent thematic areas based on careful consideration, and formulating interview questions that directly reference these themes. Structuring interviews around these themes allows for the gathering of comprehensive data that enhances understanding and meets research objectives effectively. Aligning interview content with findings from the literature ensures relevance and meaningfulness for participants, thereby enriching overall research outcomes.

4.3   Systematic Literature Review

The SLR methodology is utilized to conduct an examination of existing scholarly literature related to the impacts of COVID-19 on software development projects. Following the guidelines established by Kitchenham and Charters (2007), this approach ensures a rigorous and transparent analysis of relevant literature.

4.3.1   The Motivation for a Literature Review

There are two major driving forces behind the motivation to conduct a systematic review on the long-term impacts of COVID-19 on software development projects in the public sector. Firstly, there is a need to consolidate all available information on this subject. Secondly, this information must be gathered comprehensively and without bias to ensure accurate conclusions.

The purpose of the systematic review is to address specific questions aimed at identifying and/or framing future research activities. The aim of this study is to examine lasting impacts of COVID-19 on software development projects in public sector. So, the research questions in this systematic review are found:

- **SLR_RQ1:** What is the state of research on the COVID-19-situation in software development and IT projects?

    o **SLR_RQ1.1:** What are the identified **impacts** of COVID-19 in software development and IT projects?

    o **SLR_RQ1.2:** What are the identified **challenges** of COVID-19 in software development and IT projects?

    o **SLR_RQ1.3:** What are the identified **recommendations** of COVID-19 in software development projects?

As outlined by Kitchenham and Charters (2007), the initial step in this review process involves determining whether a new review is necessary by identifying and examining any existing systematic reviews on the topic. Reviews covering the impacts of COVID-19 in software development projects were searched. So, the search string must include the following keywords:

- Impact or impacts. So: ("impact* of")
- COVID-19, pandemic or epidemic. So: ("covid-19" OR "pandemic" OR "epidemic")
- software development, software projects, ("software development" OR "software project*" OR "IT department*")

These keywords have to be searched in the title of papers to reduce noise in the results by searching string:

- ("impact*" AND ("covid-19" OR "pandemic" OR "epidemic") AND ("software development" OR "software project*" OR "IT department*"))

4.3.2 Development of a Review Protocol

A review protocol was developed for the evaluation of the literature to ensure that information is queried consistently in scientific databases, and later mapped and summarized. A self-developed data extraction template assists in summarizing the information.

4.3.3 The Search Strategy

The literature search was conducted using popular internet databases that encompass a wide range of sources including journals and conferences.

Various options were considered, but Google Scholar was discarded due to its broad coverage across different subjects, resulting in a significant amount of non-relevant works in the search results.

Ultimately, the selected databases for conducting the systematic review were:

- ACM (Association for Computing Machinery)
- IEEEXplore (Institute of Electrical and Electronics Engineers)
- Springer

For the state-of-the-art search, the focus was on identifying works that utilize lasting impacts of COVID-19 on software development projects in public sector. Synonyms were considered, such as using "effects" instead of "impacts" and "pandemic" or "epidemic" instead of "COVID-19".

The timeline was set from 2019 to 2024 in the mentioned databases to exclude non-COVID-19-related papers and minimize noise in the search results.

The search was conducted in titles, abstracts, and/or keywords, as these areas are most likely to contain relevant terms. Full-text searching was avoided to minimize irrelevant results and noise.

This is the strategy employed for searching primary studies and extracting data. The review process involves the following steps:

1. The search string was started on selected databases.
2. Duplicate works were deleted.
3. Titles of papers were sorted into relevant and non-relevant categories.
4. Abstracts of papers were sorted into relevant categories.
5. For papers that remain relevant after title and abstract review, a detailed content review is conducted.
6. This data is entered into a template designed to outline the main characteristics of each paper, serving as a guide for subsequent classification and easier data extraction.

4.3.4 Data Extraction Template

A template is created to specify the information that needs to be extracted from each scientific paper. This is designed to gather relevant data present in the studies, facilitating their classification later. The template is outlined in Table 1:

Topic	Description
Domain	What domain in software development or IT projects was researched?
Methodology	What methodology was employed in the study?
Type of Research	Quantitative or qualitative
Impacts of COVID-19	How does the study address the lasting impacts of COVID-19 on software development projects (in the public sector) in a goal-oriented manner?
Challenges Identified	What challenges related to COVID-19's lasting impacts on software development projects in the public sector were identified in the study?
Solutions Proposed	What solutions or recommendations are proposed in the studies reviewed?

Table 1: Data Extraction Template

4.4 Thematic Areas for Interview Questions

After conducting a structured analysis of existing literature, thematic input for semi-structured interviews must be developed to capture relevant information. This step is crucial for gaining deeper insights into the research problem. It involves identifying and integrating common themes from the literature, organizing them into coherent thematic areas based on careful consideration, and formulating interview questions that directly reference these themes. Structuring interviews around these themes allows for the gathering of comprehensive data that enhances understanding and meets research objectives effectively. Aligning interview content with findings from the literature ensures relevance and meaningfulness for participants, thereby enriching overall research outcomes.

To construct thematic areas for interview questions in semi-structured interviews, the following steps are undertaken:

1. Identifying the main topics of the papers to build the main topics of the interview questions.
2. Formulate interview questions based on the identified thematic areas.

4.5 Semi-Structured Interviews

In addition to the SLR, semi-structured interviews are conducted with key stakeholders from the digital department of a Viennese public organization. These interviews aim to gather in-depth, context-specific experiences and perspectives on the lasting impacts of COVID-19 on software development projects in the public sector.

4.5.1 Approach Motivation & Objectives

The motivation for employing semi-structured interviews in my master's thesis stems from several key factors:

Flexibility and Depth: Semi-structured interviews provide the flexibility to explore complex topics in depth. This is crucial for understanding the nuanced and multifaceted impacts of COVID-19 on software development projects, which can vary significantly across different public sector contexts. The semi-structured format allows me to probe further into interesting or unexpected responses, thereby gaining a richer and more comprehensive understanding of the subject matter.

Balance of Structure and Openness: Unlike structured interviews, which can be too rigid, or unstructured interviews, which can lack focus, semi-structured interviews strike a balance by using a predefined set of questions while allowing for open-ended responses. This balance ensures that key topics related to the impact of COVID-19 are covered systematically, while also permitting participants to express their experiences.

Capturing Detailed Personal Experiences: The pandemic has affected individuals and organizations in diverse and profound ways. Semi-structured interviews are particularly effective at capturing detailed personal experiences and subjective perspectives. This method is well-suited for uncovering how public sector software development projects have adapted to new challenges, the strategies employed, and the long-term effects on processes and outcomes.

Eliciting Rich, Qualitative Data: The qualitative data obtained through semi-structured interviews can provide deep insights into the human and organizational dimensions of the pandemic's impact. This richness of data is essential for developing a comprehensive understanding of how software development projects have been reshaped in the public sector, going beyond what quantitative data alone can reveal.

Adaptability to Emerging Themes: While interviews, new themes and patterns may emerge that were not initially anticipated. The semi-structured format allows for the adaptation of questions based on these emerging themes, ensuring that the research remains responsive and relevant to the lived experiences of participants.

4.5.2 Interviewees – Selection Criteria for Experts

Semi-structured interviews were conducted within a public organization in Austria to present an overview into the lasting impacts of COVID-19 on software development projects. In the following subsection is a detailed overview about the selection criteria.

Selection Criteria of Interview Experts:

The experts were informed that participation in the interviews was entirely voluntary. Furthermore, all participants provided their consent for the interviews to be recorded via Google Meet for transcription purposes. These recordings were deleted after the transcription process was completed. The analysis was carried out in an anonymized form to ensure confidentiality.

The main criterion was that the expert had worked at the organization before, during, and after the pandemic. The experts were carefully selected based on their extensive and long-standing experience in the public sector, as well as their role within the software projects. Each expert occupies a senior or specialist role in large-scale software development projects, ensuring they provide comprehensive expertise essential for this research.

Five experts from the digital department were interviewed, all of whom have extensive experience in managing software development projects and have been long-term employees within this organization, specifically in the public sector.

Their deep-rooted expertise and firsthand experiences provided valuable perspectives on how the COVID-19 has influenced software development projects, and adaptations implemented in response to the crisis. When interview partners were selected, attention was given to the following characteristics:

Age: The age of interviewees was considered to ensure a diverse range of perspectives and experiences in the research area.

Current Position: The current job role of each interviewee was evaluated to ensure insights from various functional areas within the organization.

Number of Experts in Leadership Roles: The number of interviewees in leadership positions was evaluated to ensure that perspectives from individuals with strategic oversight and decision-making responsibilities were included.

Professional Experience in Current Position: The duration of time each interviewee has spent in their current role was assessed to understand the depth of their expertise and experience.

Length of Employment in the Public Sector: The length of employment in the public sector refers to the number of years an individual has worked in the public sector, which is equivalent to the number of years they have spent with their current organization.

Scale of Previous Projects: The scale of the projects each interviewee has worked on was considered to gather insights from individuals with experience in projects of varying sizes and complexities. The complexity of projects within the organization is assessed using story points per release, as follows:

- **Value 1 (under 20 Story Points per Release):** Very low complexity. The scope of changes and additions per release is minimal. Suitable for small projects or very simple tasks.
- **Value 2 (20 - 99 Story Points per Release):** Low complexity. The scope of work per release is manageable. Suitable for small to medium-sized projects with moderate change requirements.
- **Value 3 (100 - 299 Story Points per Release):** Medium complexity. The scope of tasks per release is significant but still manageable. Suitable for medium-sized projects with regular needs for changes and extensions.
- **Value 4 (300 - 999 Story Points per Release):** High complexity. The scope of work per release is substantial and requires thorough planning and coordination. Suitable for large projects with complex requirements.
- **Value 5 (more than 1000 Story Points per Release):** Very high complexity. The scope of changes and additions per release is enormous. Suitable for very large and complex projects that require extensive planning and numerous resources.

Number of Projects Involved: The number of projects each interviewee has participated in.

This table contains information about the experts in anonymized form:

	Size of the Sample n = 5
Age	MAX: 61 AVG: 50 MIN: 40
Highest Educational Qualification	1x Mag., 3x MSc., 1x HTL
Actual Position	2x IT Demand Manager, 2x Application Manager, 1x CIO
Number of Experts in Leadership Role	1
Professional Experience in Current Position	MIN: 7 AVG: 13 MAX: 18
Length of Employment in Public Sector	MIN: 6 AVG: 18,8 MAX: 29
Scale of Previous Projects (1 - Small, 3 - Medium, 5 - Large)	MIN: 4 AVG: 4,8 MAX: 5
Number of Projects Involved	MIN: 2 AVG: 3,2 MAX: 5

Table 2: Description of interview partners (experts) for semi-structured expert interviews

4.6   Evaluation Process based on Mayring's Method

The method, developed by Mayring (2014), was employed to systematically analyze the data collected through semi-structured interviews.
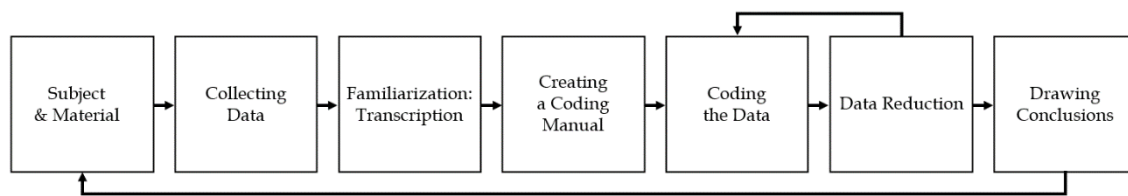

Figure 8: The Steps applied from Mayring's Method (2014)

The following steps outline the application of this method:

Subject & Material: In this step, the focus of the evaluation was determined: the lasting impacts of COVID-19 on software development projects in the public sector. The primary material for the analysis consisted of the interview transcripts.

Collecting Data: Data was gathered through semi-structured interviews with experts from the public sector involved in software development projects. These interviews were conducted in the form of video conferences via *Google Meet* and were recorded using Google Meet Recording. They provided rich, qualitative insights into how COVID-19 has impacted their work and the adaptations made in response.

Familiarization – Transcription: After the interviews were conducted, the recordings were transcribed using the transcription tool, *Cockatoo*.

- The transcripts were then exported to MS Word and thoroughly reviewed. During this review process, the Google Meet Recordings were listened to correct any inaccurately transcribed sections.
- The interviews were conducted in German, the Google Meet recordings were translated from German to English. The translation of the document was done using the tool, Online Doc Translator.

Creating a Coding Manual: Then, a coding manual was developed to standardize the process of data analysis. **Three main categories** were established to examine the insights, particularly focusing on the impacts of COVID-19 on software development projects in the public sector:

- "Pre-COVID-19 Landscape "
- "Operational Adjustments During COVID-19",
- and "Post-COVID-19".

Coding the data: During this phase, the interview data was systematically coded in alignment with the categories established in the coding manual. This process entailed tagging specific text segments with codes that corresponded to various themes pertinent to the impacts of COVID-19 on software development projects.

The transcripts in Englisch were imported into *MAXQDA*, where it was organized and coded under the main categories.

An inductive approach was employed, meaning that codes were not predefined but were generated from the data itself as patterns and themes emerged through the analysis. This method allowed for a more nuanced and data-driven understanding of the impacts observed. A coding matrix was also created to organize and visualize the coded data. This matrix mapped out the relationships between different codes and categories, facilitating the identification of patterns and trends across the interview responses.

Data Reduction: After Coding 10-50% of data, a data revision was employed to filter redundancy in codes. The data reduction also involved summarizing and condensing the coded data to focus on the most relevant information.

Drawing conclusions: Finally, conclusions were drawn based on the analyzed data. This involved interpreting the patterns and themes identified through the coding process to understand the lasting impacts of COVID-19 on software development projects in the public sector, and how these insights contribute to the broader research objectives of the thesis.

4.7   Summary

The methodology uses a mixed-methods approach with a multi-phase research process covering before, during, and after COVID-19 to explore its lasting impacts on public sector software development projects.

The research process begins with a **Systematic Literature Review (SLR)**, aimed at gathering and synthesizing existing scholarly literature on the topic. This review follows the guidelines outlined by Kitchenham and Charters (2007) to ensure a rigorous and transparent analysis. The motivation behind conducting this review is to compile a comprehensive and unbiased summary of the current knowledge on the effects of COVID-19 on software development projects. To achieve this, the review protocol includes specific search strategies using databases such as ACM, IEEExplore, and Springer, and employs precise keywords to focus on relevant studies. The SLR is structured to address several research questions regarding the state of research, impacts, challenges, and recommendations related to COVID-19 in software development.

Following the SLR, thematic areas for semi-structured interviews were developed to capture nuanced information related to the research problem. This process involved synthesizing common topics from the literature into coherent categories and crafting interview questions that address these topics. The structured approach to formulating interview questions ensures that the interviews resulted relevant data, aligning with the objectives of the research.

Semi-structured interviews were conducted with five experts from the digital department of a public organization. The purpose of these interviews was to obtain context-specific insights into the effects of COVID-19 on software projects.

Creating a coding manual involves establishing three primary categories, Pre-COVID-19 Landscape ", Operational Adjustments During COVID-19, and Post-COVID-19. These categories guide the thematic analysis of the interview data, ensuring that insights are systematically organized and relevant to the research objectives. The manual helps structure the analysis to enhance understanding and relevance.

Coding the data is conducted using MAXQDA, where an inductive approach is applied. Codes are not predefined but emerge from the data itself as themes and patterns are identified. This allows for a data-driven analysis that reflects the actual experiences and impacts reported by participants.

Developing a coding matrix and data reduction are integral to organizing and synthesizing the coded data. This process involves creating a matrix to visualize relationships between codes and summarizing the data. Data display includes the findings in a structured format to facilitate interpretation.

Finally, drawing conclusions involves integrating the data from both the literature review and interviews to derive comprehensive insights into the lasting impacts of COVID-19 on software development projects.

5 Systematic Literature Review based on Kitchenham and Charters

The following section outlines the review process, including the search for works across various databases, the selection of primary studies, and the data extraction.

5.1 Conducting the Search

This section addresses the initial steps of the review protocol. By using the search string in the database search engines, numerous results were obtained. These results were collected in Microsoft Excel, where duplicates and non-relevant works were removed after reviewing their titles and abstracts. The following steps describe the search process:

1. **Performing the Search:** Performing the search with the specified command.

2. **Using the Range "2019-2024":** To obtain COVID-relevant results, a date range from 2019 to 2024 was set for searches across the three databases.

3. **Advanced the Filter Criteria "Content Type" & "Discipline":** Subsequently, advanced filter criteria were applied within the databases. In the ACM database, the content type was restricted to "Research Article." Similarly, in IEEEXplore, the content type was limited to "Journals" and "Conferences." In Springer, it was not possible to apply all filter criteria at once, so the search was initially narrowed down by setting the content type to "Conference Paper" and discipline to "Computer Science," followed by another search using the content type "Article" and discipline "Computer Science." In Springer, it was necessary to specifically use the discipline "Computer Science" to filter out noise from other fields.

4. **Checking Duplicates:** In this step, duplicates were filtered and deleted based on their titles in Microsoft Excel.

5. **Checking Title:** At this stage, the titles of the papers were reviewed. Papers that were not relevant based on their titles were excluded and deleted. The number of papers remaining in each database is as follows:

6. **Checking Abstract:** At this point, the abstracts of the papers were evaluated. Papers deemed irrelevant based on their abstracts were excluded and removed. The remaining number of papers is a total of 23.

7. **Checking Text:** In step 7, the papers with relevant summaries were read. This step resulted in 22 scientific papers being included in the systematic review.

8. **Citing Papers:** While reviewing the full texts of the papers, the framework outlined in Table 1 was completed for each article. The analysis of the studies and the data extracted from each one are presented in Section 5.2. A total of 22 papers were analyzed and cited.

The following table presents the process and the number of papers at each step at each database. The numbers in brackets indicate how many papers were excluded at each step. The final row shows the total sum of papers each step:

	Step 1: Initial N° of papers	Step 2: N° of papers after using range	Step 3: N° of papers after using advanced filter criteria	Step 4: N° of papers after checking duplicate	Step 5: N° of papers after checking title	Step 6: N° of papers after checking abstract	Step: 7 N° of papers after checking text	Step 8: N° of papers cited
ACM	1499	(-72) 1427	(-615) 812	(-6) 806	(-794) 12	(-4) 8	(-1) 7	(-0) 7
IEEExplore	77	(-3) 74	(-2) 72	(-0) 72	(-60) 12	(-5) 7	(-0) 7	(-0) 7
Springer	10181	(-611) 9570	(-8393) 1177	(-6) 1171	(-1153) 18	(-10) 8	(-0) 8	(-0) 8
Sum	11757	(-686) 11071	(-9010) 2061	(-12) 2049	(-2007) 42	(-19) 23	(-1) 22	(-0) 22

Table 3: Distribution of Papers by Process Step Across Databases

This figure shows the number of papers each database each step. On the top is the final step with the number of papers cited:
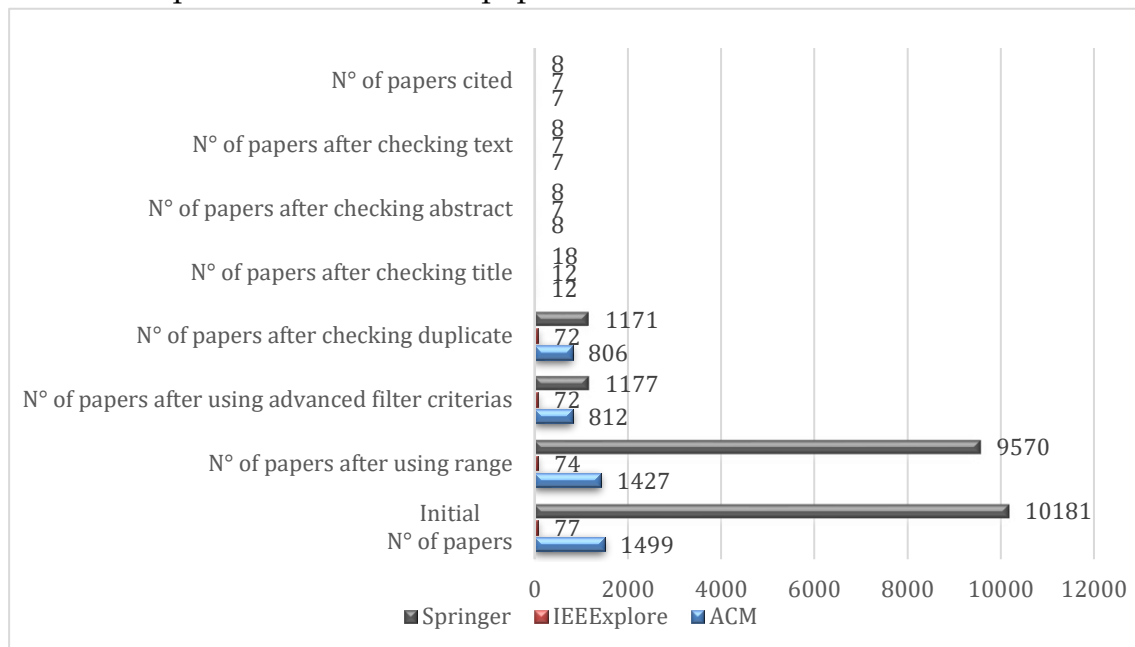

Figure 9: Distribution of Papers by Process Step Across Databases
(Blue: ACM, Red: IEEE Xplore, Green: Springer)

5.2   Evaluation of Studies

Based on the established criteria and protocols outlined in the previous sections, the selected articles highlight various approaches to utilizing impacts on software development projects within the public sector, particularly in the context of COVID-19.

5.2.1   Papers from ACM

This subsection focuses on analyzing and citing the papers from the ACM database using the "Data Extraction Template." The objective is to systematically arrange the findings and insights from the chosen studies, offering a detailed overview of the research landscape in this domain.

Neumann et al. (2022) highlighted how the COVID-19 pandemic has prompted a transition in software development teams from home office. This shift led to rapid adjustments in agile practices and roles, with communication becoming more objective while social interactions decreased. Despite facing challenges, team members expect a combination of remote and onsite work in the post-pandemic landscape. Notably, the performance and well-being of team members have either remained stable or improved. The findings support existing research on the pandemic's effects on agile software development teams, underscoring their successful adaptation to remote work environments.

Neumann et al. (2022) have outlined the following key insights:

Neumann, M. et al. (2022)	Description
Domain	Software development (Agile)
Methodology	Case study
Type of Research	Qualitative
Impacts of COVID-19	Post-pandemic impacts: Combined approach of remote and onsite work Decrease in social exchange Stable or increased performance and well-being
Challenges Identified	Remote work integration Changes in communication dynamics Adjustments in agile practices to maintain productivity and team cohesion
Solutions Proposed	Adapting agile practices and roles to remote work conditions, enhancing communication objectivity, addressing decreased social exchange, and preparing for increased remote work and digital tool usage in the future.

Table 4: Data Extraction Table for the Paper of Neumann, M. et al. (2022)

Müller et al. (2023) focused on the challenges encountered by agile teams during the COVID-19 pandemic, particularly concerning distributed collaboration. The study emphasized the significance of trust and self-responsibility within these teams, addressed various collaboration challenges, and offered recommendations aimed at enhancing team satisfaction and productivity.

Müller et al. (2023) have presented the essential findings:

Müller, K. et al. (2023)	Description
Domain	Software development (Agile)
Methodology	Mixed methods research
Type of Research	Quantitative (online survey) and qualitative (semi-structured interviews)
Impacts of COVID-19	Work in home office during the pandemic influenced productivity and decision-making processes
Challenges Identified	Trust issues Collaboration difficulties Management challenges in distributed teams
Solutions Proposed	Focusing on agile and collaborative working modes, fostering trust and self-responsibility, and transferring decision-making power to teams

Table 5: Data Extraction Table for the Paper of Müller, K. et al. (2023)

Bezerra et al. (2021) investigated the effects of working from home office on Brazilian software engineering teams during the COVID-19. The findings revealed that home office induced significant changes in work routines, notably an increased workload and extended working hours. Despite these challenges, the study observed that collaboration and communication within teams remained positive. Participants reported enhanced productivity and a general sense of satisfaction with the home office arrangement, highlighting the adaptability and resilience of the teams in navigating the new work environment. The researchers conducted a survey involving 67 participants to examine the tools used during work from home office and the frequency of meetings. The first graphic illustrates the various tools adopted by individuals to facilitate remote work, while the second graphic provides insights into how often these participants engaged in meetings. These visual representations offer a comprehensive overview of the technological adaptations and communication practices among the surveyed group in the context of work in home office. The work in home office resulted in changes in work routines, including increased workload and exceeding standard hours. Collaboration and communication among team members remained positive. Participants reported improved productivity and satisfaction with the work in home office. Companies provided support such as laptops, headsets, and monitors for work in home office. The figure below illustrates the percentage of respondents using different video conferencing tools, as reported in the study by Bezerra et al. (2021). The study

found that Google Meet was the most widely used tool, accounting for 20.54% of users. Microsoft Teams followed closely with a usage rate of 20%:
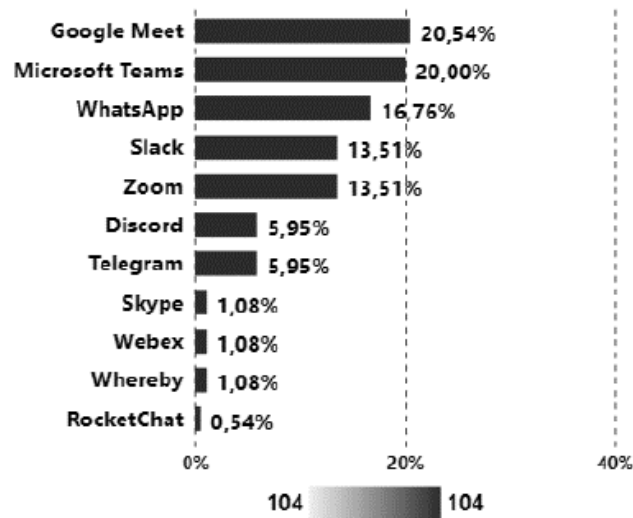

Figure 10: Tools in remote communication (according to Bezerra, C. et al. 2021)

The following figure shows that most respondents have one online meeting per day while working from home. Less than a third of the respondents reported having two meetings per day:
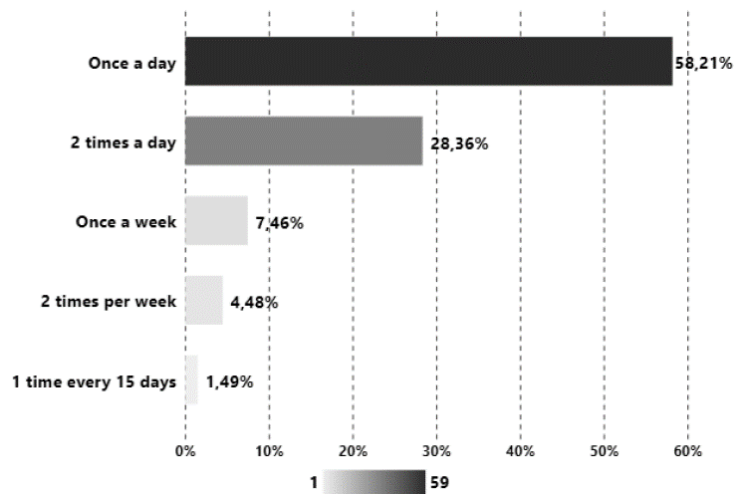

Figure 11: Frequency of meetings in home office (according to Bezerra, C. et al. 2021)

The following table presents the information according to the SLR data extraction rules:

Bezerra, C. et al. (2021)	Description
Domain	Software development teams working in home office
Methodology	Survey
Type of Research	Qualitative and quantitativ
Impacts of COVID-19	Changes in work routine: • Increased workload • Exceeding standard business hours Impacts on work process: • Improved productivity • Positive collaboration
Challenges Identified	Increased workload Changes in work routines Managing work-life balance Psychological well-being, insomnia, childcare responsibilities Adjustments in the software development process
Solutions Proposed	No

Table 6: Data Extraction Table for the Paper of Bezerra, C. et al. (2021)

Da Silva et al. (2023) highlighted that the communication, encompassing speaking and listening, is essential for effective collaboration within software development teams. The COVID-19 pandemic has led software developers to prioritize soft skills such as teamwork, fast learning, ethics, responsibility, problem-solving, and proactivity. While the pandemic has positively influenced developers' soft skills—enhancing flexibility, empathy, adaptability, and a willingness to learn—it has also adversely affected motivation and emotional resilience. Therefore, soft skills such as teamwork, fast learning, ethics, responsibility, problem-solving, and proactivity were essential for software developers. The active listening is crucial for effective communication within software development teams. Despite challenges, software developers have showcased resilience and adaptability in the face of adversity.

The researchers illustrated the essential soft skills and the influence of COVID-19 on these competencies. Notably, several soft skills are critical for developers' success, including flexibility, adaptability, empathy, and productivity. This figure represents the importance of these skills in the context of the pandemic's impact on the software development industry:
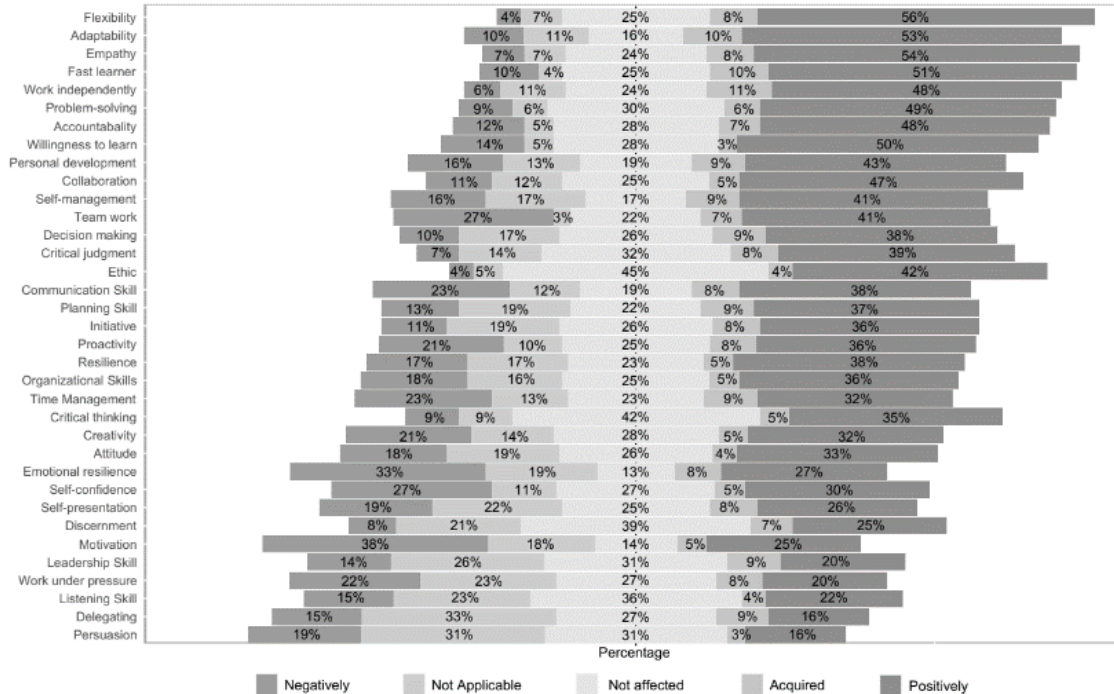

Figure 12: Percentage of impacts experienced by developers' soft skills (according to da Silva, R. M. et al., 2023)

Below is a table summarizing the details in line with the SLR data extraction guidelines:

da Silva, R. M. et al. (2023)	Description
Domain	Soft Skills of Software Developers:
Methodology	Survey
Type of Research	Quantitative
Impacts of COVID-19	Impact of COVID-19 on Soft Skills: • Positive changes in adaptability, empathy, and continuous learning • Negative impacts on motivation and emotional resilience
Challenges Identified	The need for developers to rapidly adapt to remote work dynamics, cope with uncertainties, refine self-management, organizational skills, and flexibility to ensure productivity, maintain equilibrium between personal and professional spheres, enhance communication skills, utilize virtual collaboration tools, and emphasize teamwork for project success.
Solutions Proposed	Implementing training programs focused on improving soft skills for software developers

Table 7: Data Extraction Table for the Paper of da Silva, R. M. et al. (2023)

Qahtani (2022) compared the process before and during the pandemic to identify challenges and measure its impact on the number of requirements completed and development project resources. The results showed that the pandemic changed requirement elicitation techniques, increased the number of completed requirements, and necessitated adjustments in human resources due to remote communication. Furthermore, the researchers have modeled the requirements engineering scenario, outlining the differences between the client's site and the vendor's site before and after COVID-19. This model highlights the changes in processes and interactions, providing a comprehensive view of how the pandemic has impacted both sides of the development process:
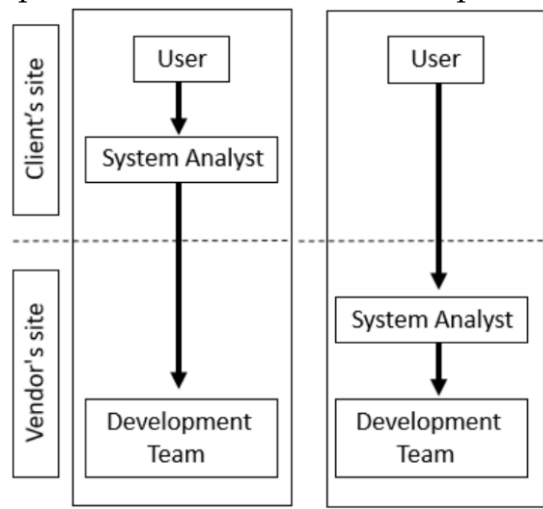

Figure 13: Development Scenario Before (left) and After (right) the Covid- 19
        (according to Qahtani, A. M., 2022)

The table below outlines the data extracted as per SLR rules:

Qahtani, A. M. (2022)	Description
Domain	Requirements engineering in software development
Methodology	Case study
Type of Research	Qualitative
Impacts of COVID-19	Changes in Requirement Elicitation Process: • Increased number of requirements collected remotely • Reduced time for requirements analysis Impact on Human Resources: • Reduction in system analysts allocated at client sites • Shift to remote work for system analysts at vendor's site
Challenges Identified	Complicated communication between development team members due to remote work. Difficulty in understanding and executing customer requirements. Increased requirements
Solutions Proposed	The study proposes adopting remote communication tools and agile development approaches to collect and analyze requirements during the COVID-19.

Table 8: Data Extraction Table for the Paper of Qahtani, A. M. (2022)

Neves de Souza et al. (2023) examine the impact of communication channels on software development teams, highlighting the importance of digital tools and the challenges encountered, particularly during the COVID-19 pandemic. They show how teams adapted to remote work by relying on digital tools like private chats for communication.

However, the transition to remote work has not been without challenges. Teams face issues such as asynchronous communication, scheduling conflicts, and technical difficulties, which complicate collaborative efforts. The pandemic has also had mixed impacts on team communication. On the positive side, it has increased the availability for remote interactions, enabling more frequent communication. On the negative side, the absence of in-person interactions has hindered problem-solving capabilities. Understanding the impact of various communication channels on team dynamics is crucial for enhancing collaboration and productivity.

To address these challenges, Neves de Souza et al. (2023) suggest several guidelines for improvement, such as setting specific online availability times to ensure synchronous interactions, and leveraging tools designed for asynchronous communication to manage tasks and deadlines effectively.

The following table organizes the information based on SLR data extraction standards:

Neves de Souza, A. et al. (2023)	Description
Domain	Software Development
Methodology	Mixed methods research: Comparative analysis and survey
Type of Research	Qualitative and Quantitative
Impacts of COVID-19	Using more virtual communication channels
Challenges Identified	Adapting communication processes and tools for synchronous and asynchronous communication. Increased workload due to remote work was noted as a significant impact. The need for adjustments to deal with problems and the reinforcement of communication tools for better traceability were also mentioned as challenges.
Solutions Proposed	Clear identification of activities in the development process and support for tracking each other's activities through appropriate tools or specific processes. Creating reporting outlets for daily activities, pre-scheduling regular individual contacts, and defining specific online availability times for team members. Encouraging introverted developers to communicate and clear up communication barriers through structured reporting meetings and group communication channels.

Table 9: Data Extraction Table for the Paper of Neves de Souza, A. et al. (2023)

Bezerra, C. I. et al. (2020) highlighted the importance of factors like work environment, task management, emotional well-being, and communication on productivity. Recommendations for improvement included ergonomic material supply, infrastructure enhancements, and better communication tools.

The survey, completed by 58 participants, yielded the importance of effective task distribution and turnover management for productivity in remote teams. Maintaining regular working hours has positively impacts productivity. Clear and efficient communication tools are essential for collaboration and productivity. Furthermore, motivation, emotional well-being, and health play a significant role in ensuring productivity. Company support in providing resources and assistance is vital for remote work productivity.

Presented in the table are the details according to the SLR data extraction framework:

Bezerra, C. I. et al. (2020)	Description
Domain	Software development teams (Productivity)
Methodology	Survey
Type of Research	Quantitative and qualitative
Impacts of COVID-19	Remote Communication: Importance of Clear Communication Tools for Effective Communication Motivation, Emotional, and Health: • High Motivation Levels • Emotional Well-being and Health Maintenance
Challenges Identified	Challenges and Enhancements in Remote Work
Solutions Proposed	Support in home office: • Financial and Material Assistance • Support for Remote Work Performance

Table 10: Data Extraction Table for the Paper of Bezerra, C. I. et al. (2020)

5.2.2 Papers from IEEExplore

This subsection examines and references the papers sourced from the IEEExplore database utilizing the "Data Extraction Template." The aim is to systematically organize the findings and insights from the selected studies, providing a comprehensive overview of the research landscape in this field.

The COVID-19 pandemic has profoundly affected software development, influencing projects and professionals worldwide. A comprehensive study by Neto, P. A. D. M. S. et al. (2021) examined 100 Java projects on GitHub and surveyed 279 software development professionals to explore the multifaceted effects on productivity, code quality, and well-being. The study revealed that developers experienced increased stress and sleep disorders, coupled with a reduction in mentoring activities for newcomers. Productivity was not significantly impacted by interruptions, and household size did not correlate with the frequency of interruptions. Organizations can better support developers by providing flexibility, enhancing communication, and offering mental health resources.

The information in the following table has been compiled according to SLR data extraction criteria:

Neto, P. A. D. M. S. et al. (2021)	Description
Domain	Software Development
Methodology	Statistical Analysis and Survey
Type of Research	Quantitative and Qualitative
Impacts of COVID-19	Remote Work: The shift to remote work has allowed software developers to work from anywhere, increasing flexibility and potentially improving work-life balance. Increased Collaboration: Virtual collaboration tools have enabled teams to work together effectively, contributing to improved communication and teamwork. Agile Adaptation: Agile methodologies have become more prevalent, allowing teams to quickly adapt to changing requirements and deliver software more efficiently. Burnout: Developers reported increased stress and sleep disorders, with decreased mentoring activities for newcomers.
Challenges Identified	Communication Challenges: Remote work can lead to communication gaps and misunderstandings among team members, impacting productivity and project outcomes. Technical Challenges: Limited access to hardware, software, or data centers may hinder development progress and quality.
Solutions Proposed	More small breaks during working hours Separating work hours from personal and family time

Table 11: Data Extraction Table for the Paper of Neto, P. A. D. M. S. et al. (2021)

Challenges such as remote work, budget constraints, and the need for infrastructure upgrade are some of the challenges that have been caused by the COVID-19 epidemic. The researchers have identified that the COVID-19 pandemic has accelerated digital transformation and forced companies to reevaluate their IT operations. Remote work has become a crucial aspect of post-pandemic business operations, leading to a shift in workplace dynamics. Budget freezes and decreases have pushed companies to prioritize essential IT investments and optimize operational costs. Infrastructure upgrades and increased demand for digital services have become key trends in the IT service management sector. Companies are focusing on refining processes, adapting to remote work models, and updating business continuity plans (Mitev, Y. R., & Dimitrov, D. I. 2021).

The information in the following table has been compiled according to SLR data extraction criteria:

Mitev, Y. R., & Dimitrov, D. I. (2021)	Description
Domain	IT Service Management
Methodology	Literature Review
Type of Research	Qualitative
Impacts of COVID-19	Accelerated Digitalization: • Companies pressed to accelerate digitalization to survive • Increased demand for cloud applications and public cloud hosting
Challenges Identified	Budget freezes or decreases Infrastructure upgrades Remote working adoption Processes refinement Accelerated digitalization
Solutions Proposed	No

Table 12: Data Extraction Table for the Paper of Mitev, Y. R., & Dimitrov, D. I. (2021)

Hooshyar, H. et al. (2023) investigated the impact of COVID-19 on software engineering after pandemic restrictions. Startups encountered difficulties in requirements gathering, whereas established companies experienced positive outcomes in architecture and quality assurance. Their study highlighted that remote work had a positive impact on certain activities for established companies, while software startups faced challenges in communication and collaboration. It suggests that team dynamics, communication tools, and work habits may significantly influence the determination of impact. Adaptation, communication, and collaboration are important for maintaining productivity and quality in software development.

The table provides an overview of data extracted in compliance with SLR rules:

Hooshyar, H. et al. (2023)	Description
Domain	Software development
Methodology	Literature review, Survey, Data analysis
Type of Research	Quantitative and qualitative
Impacts of COVID-19	Negative impact on requirements engineering. Positive impacts on software architecture and quality assurance
Challenges Identified	Communication and collaboration Maintaining productivity Managing project timelines and deadlines.
Solutions Proposed	Adaptation, communication, and collaboration are crucial for maintaining productivity and quality.

Table 13: Data Extraction Table for the Paper of Hooshyar, H. et al. (2023)

Ma, L. et al., (2022) analyzed the impact of emergencies, specifically COVID-19, on OSS development using a metric-based approach across various dimensions. Results showed impacts on software projects, with no exacerbation when emergencies recur. The proposed model identified vulnerable areas and developed contingency plans. The development risk metrics increased during the progression of the epidemic, affecting over 72.4% of projects negatively.

Below is a table that displays the extracted data per SLR guidelines:

Ma, L. et al. (2022)	Description
Domain	Open-Source Software (OSS) development
Methodology	Experiment: metric-based analysis
Type of Research	Quantitative
Impacts of COVID-19	Changes in team activity, development activity, and development risk metrics
Challenges Identified	Reduced development efficiency Blocked development processes Delayed development plans
Solutions Proposed	No

Table 14: Data Extraction Table for the Paper of Ma, L. et al. (2022)

Schmidtner, M. et al. (2021) reported that the COVID-19 has shifted working practices towards remote collaboration, and companies had implemented emergency plans and new protective measures. Furthermore, they highlighted that there was a smooth transition to home office with a small decrease in productivity. The use of mobile hardware and video conferencing tools had

increased. There was a decline in using project management tools. Expectation of home office became a part of the future work environment. New experiences led to significant changes in work practices. Before COVID-19, 84% of respondents were able to work from home 25% of the time or less. During COVID-19, this completely changed, with 66% of respondents working from home 75-100% of the time:
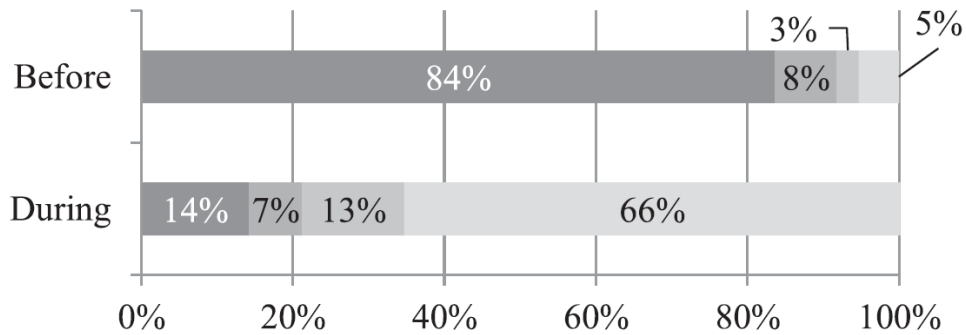

Figure 14: Home office both before and during the COVID-19 pandemic (according to Schmidtner, M. et al., 2021)

The following table is organized according to the rules set by the SLR data extraction process:

Schmidtner, M. et al. (2021)	Description
Domain	Software project management (Agile)
Methodology	Survey
Type of Research	Qualitative
Impacts of COVID-19	Increased Flexibility: • Video conferencing tools crucial • Cloud storage facilitating collaboration Resilience and Adaptability: • Smooth transition to home office • Increase in mobile hardware usage
Challenges Identified	No
Solutions Proposed	Implementing flexible working arrangements, utilizing digital tools for remote collaboration, and preparing for future disruptions to ensure business continuity.

Table 15: Data Extraction Table for the Paper of Schmidtner, M. et al. (2021)

Despite some alterations in software engineers' activities during COVID-19, such as reduced time spent on bug fixing and increased focus on testing and documentation, there was no significant overall impact on their well-being or productivity. Major tech companies are increasingly adopting remote work, suggesting a positive outlook for the future. Russo, D. et al. (2021) highlighted

that the pandemic led to transitioning software developers to work in home office. There was a minimal impact on their well-being and productivity.

In the table below, the data is presented following the SLR extraction rules:

Russo, D. et al. (2021)	Description
Domain	General purpose in software engineering
Methodology	Mixed methods: Survey and analyzing metrics
Type of Research	Quantitative and qualitative
Impacts of COVID-19	Less time on bug fixing and meetings More time on testing and documentation
Challenges Identified	Maintaining communication, collaboration, work-life balance, potential impacts on team dynamics and project timelines
Solutions Proposed	No

Table 16: Data Extraction Table for the Paper of Russo, D. et al. (2021)

De Souza Santos et al. (2024) examined the factors influencing software professionals' decisions to work in the office or remotely in a post-pandemic hybrid work environment. They identified that the individual preferences, such as work-life balance and opportunities for underrepresented groups, impact the choice between remote and office work. Roles within the software project, like software testing professionals and project managers, influence the preference for office work. Commuting patterns, household configurations, and challenges in balancing work responsibilities play a significant role. The nature of the project, client expectations, and team collaboration dynamics are crucial in determining the choice between remote and office work. A balance between individual preferences, team dynamics, and organizational strategies is essential for productivity and well-being in hybrid work arrangements.

The table outlines information gathered according to the data extraction process:

de Souza Santos et al. (2024)	Description
Domain	Hybrid Work in Software Companies (Post-Pandemic)
Methodology	Case study and data analysis
Type of Research	Qualitative
Impacts of COVID-19	Shift to hybrid work in post-pandemic times
Challenges Identified	Need to balance individual preferences, team dynamics, and project requirements in hybrid work arrangements to ensure productivity and well-being.
Solutions Proposed	No

Table 17: Data Extraction Table for the Paper of de Souza Santos et al. (2024)

5.2.3   Papers from Springer

This subsection examines and references the papers obtained from the Springer database using the "Data Extraction Template." The goal is to systematically organize the findings and insights from the selected studies, providing a thorough overview of the research landscape in this area.

Marek et al. (2021) assessed the COVID-19 impacts on agile developers and the subsequent change to remote work. In this paper, it is demonstrated that Agile teams were little influenced by the pandemic because of the previous experience of a remote work environment. Continuity in terms of work pace and quality was maintained with extensive usage of online collaboration tools like Jira and Confluence. Their research revealed that the performance of agile teams in Germany remained at par even after working remotely, adjusting agile practices and roles accordingly to distributed work. Communication within agile teams became more objective and efficient, with tools like MS Teams being commonly used to facilitate collaboration and interaction within the team.

The following table captures the details based on SLR data extraction rules:

Marek, K. et al. (2021)	Description
Domain	Agile Software development Teams
Methodology	Multiple case study: Semi-stuctured interviews and viewing documentation
Type of Research	Qualitative
Impacts of COVID-19	Impacts on: • Communication between team members • Performance remained stable or improved • Better integration of product owner and stakeholders No impact: • On Product Backlog and Vision • Pace and quality of work remained undisturbed
Challenges Identified	Absence of in-person communication Physical tools (like task boards) need to be converted to digital formats Engaging and involving stakeholders becomes more challenging Establish efficient training and coaching programs for agile methodologies Onboarding and training new employees is more complicated
Solutions Proposed	No

Table 18: Data Extraction Table for the Paper of Marek, K. et al. (2021)

Kettunen, P. et al. (2021) explored the impacts of the COVID-19 pandemic on Nordic software projects through a survey conducted in 2020. The results showed that agility and resilience were crucial for companies to respond and survive during the pandemic. While most respondents reported negative

impacts, a significant portion also experienced positive outcomes such as increased business and improved well-being. The agility and resilience were essential for Nordic companies to respond to the COVID-19 pandemic. Despite negative impacts, some companies experienced positive outcomes such as increased business and improved well-being. Most respondents reported that agility helped them respond to the pandemic, with many companies improving agility during the past year. Remote working, declining business, and cooperation difficulties were significant challenges faced by companies during the pandemic. Furthermore, the agile practices played a crucial role in helping organizations navigate the challenges brought on by the pandemic.

The table provides details organized according to the data extraction guidelines:

Kettunen, P. et al. (2021)	Description
Domain	Software development
Methodology	Survey
Type of research	Quantitative
Impacts of COVID-19	Positive impacts: • More business • Enhanced digitalization Negative impacts: • Declining business • Cooperation difficulties • Impeded development, layoffs • Reduction in work hours Impacts with varied degrees: • Remote working became more prevalent • New methods of working
Challenges Identified	Declining business Cooperation difficulties Impeded development, layoffs
Solutions Proposed	Developing agility in organizations to better respond to changing business conditions quickly

Table 19: Data Extraction Table for the Paper of Kettunen, P. et al. (2021)

The shift to virtual working has presented various challenges and benefits for self-organizing agile teams. Challenges noted include the absence of face-to-face communication, coordination difficulties, decreased productivity, and leadership issues. However, benefits such as improved meeting efficiency, time saved from commuting, increased productivity, and enhanced agility have also been observed. Addressing these challenges and capitalizing on the advantages of remote work is crucial for ensuring the continued success of agile teams

throughout and beyond the pandemic. Effective communication is crucial in Agile, and the shift to remote work has emphasized its importance. Remote work may lead to challenges in conveying non-verbal cues and impact software product quality. Decreased coordination and collaboration in remote work can affect productivity and motivation. Digital tools can enhance communication efficiency in virtual working environments. Remote work may impact software product quality due to decreased coordination and collaboration, leading to potential issues in product development and delivery (Ozkan et al., 2022).

The table below is formatted in accordance with SLR data extraction principles:

Ozkan, N. et al. (2022)	Description
Domain	Software development (Scrum)
Methodology	Systematical Literature Review
Type of research	Qualitative
Impacts of COVID-19	Increased efficiency of meetings Saved time from commuting Increased agility
Challenges Identified	Leadership issues: • Difficulties in coordination, decreased productivity • Challenges in conveying non-verbal cues in virtual working environments
Solutions Proposed	No

Table 20: Data Extraction Table for the Paper of Ozkan, N. et al. (2022)

Nolan, A. et al. (2021) examined the substantial changes in work patterns for software engineers brought the shift to work in home office. Their research investigated that the shift to remote work during the pandemic has posed challenges for software development teams, including maintaining social connections and trust building. Agile methodologies have adapted to remote work, but issues such as reduced collaboration and client meetings have been reported. Technology frameworks and project sizes impact productivity in a remote work setting.

Companies need to prioritize employee well-being and offer support for remote work, including flexible work arrangements and virtual exercise programs. A hybrid model of work, combining remote and in-person work, may emerge post-pandemic. Key findings underscore the significance of ergonomic home offices, effective communication tools, and adequate support for employees during this challenging period. The study suggests that the future of software engineering may involve hybrid work arrangements, combining remote and in-person work.

This table presents information structured according to SLR data extraction rules:

Nolan, A. et al. (2021)	Description
Domain	Software development
Methodology	Multivocal Literature Review
Type of Research	Qualitative
Impacts of COVID-19	Team Management: • Management reports had to be adapted to reflect the COVID-19 situation • Informal progress tracking Communication: • Increased needs of videoconferencing tools (MS Teams, Slack)
Challenges Identified	Onboarding new employees in remote environment
Solutions Proposed	Agile methodologies adaptation Carefully monitoring of the outputs and quality of deliverables on team-basis

Table 21: Data Extraction Table for the Paper of Nolan, A. et al. (2021)

Butt, S. A. et al. (2021) assessed the challenges encountered by software industries utilizing agile methodology during the COVID-19 pandemic. Their research employed regression analysis, Cronbach alpha, and descriptive analysis on data gathered from software professionals. The findings indicated that agile methodology was less effective during the pandemic, resulting in problems such as reduced coordination, increased costs, delayed project deliveries, and diminished productivity.

Decreased coordination among team members and developers was a significant issue during the pandemic period. Increased costs, late project deliveries, and decreased productivity were observed in agile projects during the pandemic. Remote working, less satisfaction with work, and fewer client meetings were identified as major challenges faced by agile projects during the pandemic. The researchers found that agile methodology faced challenges during the pandemic, impacting coordination, cost, project deliveries, productivity, remote working, satisfaction with work, and client meetings.

The following table contains data organized as per the SLR extraction process:

Butt, S. A. et al. (2021)	Description
Domain	Agile project management
Methodology	Survey
Type of Research	Quantitative
Impacts of COVID-19	Negative impacts on quality of agile methodology, coordination, cost, time, work satisfaction, client meetings, and remote working.
Challenges Identified	Pandemic situation creates issues for team coordination Cost of projects increases during work from home
Solutions Proposed	No

Table 22: Data Extraction Table for the Paper of Butt, S. A. et al. (2021)

Griffin (2021) discussed how traditional Scrum practices led to increased waste and highlights the need for integrating Lean principles to address issues such as distractions, fatigue, and inefficiencies in Scrum ceremonies and processes.

Additionally, the researcher identified solutions by applying Lean principles to minimize waste and enhance Scrum ceremonies for remote teams. The researcher shared practical adjustments made by teams to optimize their remote Scrum practices such as implementing asynchronous Daily Scrums, pre-recording Sprint Review demos. Furthermore Griffin (2021) highlighted the significance of streamlining backlog refinement through merging backlogs and holding shorter, more focused meetings to optimize remote Scrum practices.

The information in the table below follows the rules of SLR data extraction:

Griffin, L. (2021)	Description
Domain	Software development (Scrum)
Methodology	Literature Review
Type of Research	Qualitative
Impacts of COVID-19	Decreasing waste in requirements gathering and backlog refinement Need to adapt Scrum practices for remote work
Challenges Identified	Remote setting of Daily Scrum: • Staying within the 15-minute timebox, distractions, and fatigue due to the lack of in-person interactions.
Solutions Proposed	Asynchronous Daily Scrum updates to save time Merge backlogs for efficient backlog refinement

Table 23: Data Extraction Table for the Paper of Griffin, L. (2021)

Ågren, P. et al. (2022) focused on the impact of on agile practices, highlighting the importance of stand-up meetings, retrospectives, and pair programming. The shift to remote work led to changes in communication patterns, productivity, and team dynamics. Being compelled to work remotely significantly affected practitioners, resulting in challenges in maintaining team cohesion and increased stress levels. The study emphasized the necessity for effective virtual team-building and established guidelines for remote work within a hybrid model.

The table below summarizes the data extracted following SLR standards:

Ågren, P. et al. (2022)	Description
Domain	Software development (Agile)
Methodology	Mixed methods: quantitative data analysis with qualitative interviews with industry practitioners
Type of Research	Quantitative and qualitative
Impacts of COVID-19	Focusing on key Agile practices, identifying challenges faced by practitioners, and aiming to improve productivity, well-being, communication, and meeting frequency.
Challenges Identified	Increased stress and decreased motivation due to the transition to digital communication Difficulties with hybrid meetings impacting practitioners' well-being and productivity
Solutions Proposed	Companies should consider limiting meetings for practitioners' well-being

Table 24: Data Extraction Table for the Paper of Ågren, P. et al. (2022)

Juárez-Ramírez et al. (2022) analyzed the impact of work in home office. Positive emotions and satisfaction with working from home are reported by most developers. The data showed that developers tended to focus more on individual skills like self-learning, creativity, and critical thinking rather than interpersonal skills like customer service and conflict resolution. Concerns among developers included social isolation and technology use while working remotely. Developers were more inclined to practice individual skills like self-learning, creativity, and critical thinking rather than interpersonal skills.

Presented in this table are details aligned with SLR data extraction rules:

Juárez-Ramírez, R. et al. (2022)	Description
Domain	Software development: working from home
Methodology	Survey
Type of Research	Qualitative
Impacts of COVID-19	Satisfaction with working from home
Challenges Identified	Social isolation and technology use, and the practice of various skills by software developers
Solutions Proposed	No

Table 25: Data Extraction Table for the Paper of Juárez-Ramírez, R. et al. (2022)

5.3 Discussions

This chapter discusses the findings from the systematic literature review conducted on the impacts of COVID-19 on software development and IT projects.

It begins by diving into the various impacts in the chapter 5.3.1 that the pandemic has had on these projects, highlighting both the challenges and changes experienced in the industry.

Following this, the chapter 5.3.2 delves into the specific challenges faced by software development teams and IT professionals during the COVID-19 crisis. Finally, the chapter 5.3.3 outlines a series of recommendations proposed in the literature to help manage the effects of the pandemic on software and IT projects.

5.3.1 Impacts of COVID-19 on Software Projects

This chapter discusses the impacts of COVID-19 on software development projects (SLR_RQ1.1), drawing from the scientific papers reviewed in the SLR. The analysis covers dimensions of these impacts, sorted in topics, highlighting key findings and insights from the literature to understand how the pandemic has influenced software development processes, practices, and outcomes. The following table outlines the impacts from the SLR:

Topics	Impacts	References
Home Office	Hybrid working with stable or better performance	Neumann, M. et al. (2022)
	Trust issues and collaboration difficulties	Müller, K. et al. (2023)
	Increased using of collaboration tools	Neves de Souza, A. et al. (2023)
	High motivation level in home office	Bezerra, C. I. et al. (2020)
	Satisfaction with work in home office, flexibiltity increased	Juárez-Ramírez, R. et al. (2022)
	Collaboration is better in online form	Neto, P. A. D. M. S. et al. (2021)
	Hybrid work with balancing flexiblility	De Souza Santos et al. (2024)
	Communication was positively affected	Marek, K. et al. (2021)
Productivity	Changes in work process by increased workload, improvement in productivity	Bezerra, C. et al. (2021)
	More agile and flexible work environment	Ozkan et al. (2022)
	Agile practices improved the frequency and effectiveness of meetings	Ågren et al. (2022)
	Improvements in adaptability and reduced motivation	Da Silva, R. M. et al. (2023)
Demand on Cloud Solutions	Growing demand for cloud solutions	Schmidtner, M. et al. (2021)
	Increased reliance on cloud solutions and critical role of digitalization	Mitev, Y. R., & Dimitrov, D. I. (2021)
Requirements Engineering	Stakeholder integration was better, while there was no change in reporting	Marek, K. et al. (2021)
	Increased number of requirements	Qahtani, A. M. (2022)
	More time for testing and documentation led to better software quality	Russo, D. et al. (2021)
	Decreasing waste during requirements engineering	Griffin, L. (2021)
Corporate Business	Increase in business activities and enhanced digitalization efforts, and declining business in different sectors	Kettunen, P. et al. (2021)
Team Management	Management reports were adapted	Nolan et al. (2021)
	Decline in agile methodology and managing client meetings was difficult	Butt et al. (2021)

Table 26: Impacts of COVID-19 on Software Projects According to the SLR

In this section, the topics from the table are examined in detail. The explanations offer insights into the impacts of each topic. This thorough overview is intended to highlight the importance of the topics listed.

Home office:

Neumann, M. et al. (2022) outlined the impacts of hybrid working, noting a decrease in social exchange. Despite this, they reported stable or better performance and well-being among employees.

In the realm of remote working, Müller, K. et al. (2023) identified several problems, including trust issues, collaboration difficulties, and management challenges in distributed teams.

Neves de Souza, A. et al. (2023) highlighted changes in communication, with an increase of using virtual communication tools. They also noted an unintended consequence of remote working: an increased workload. Furthermore, the researchers emphasized the need for adjustments to address these challenges and the reinforcement of communication tools for better traceability.

Bezerra, C. I. et al. (2020) explored several aspects of remote communication and its impacts on motivation, emotional well-being, and health. They emphasized the importance of clear communication and the use of tools for effective communication in a remote work setting. Additionally, their findings indicated high levels of motivation among remote workers, alongside maintained emotional well-being and health.

Juárez-Ramírez, R. et al. (2022) investigated satisfaction with working from home. Their study revealed that employees generally reported high levels of satisfaction with remote work arrangements. Factors contributing to this satisfaction included increased flexibility, better work-life balance, and the comfort of working from a familiar environment.

Neto, P. A. D. M. S. et al. (2021) examined the shift to remote work, highlighting that it has allowed software developers to work from anywhere, thereby increasing flexibility and potentially improving work-life balance. They noted that virtual collaboration tools have enabled teams to collaborate effectively, enhancing communication and teamwork. Additionally, the researchers discussed the impacts of agile adaptation and burnout.

De Souza Santos et al. (2024) investigated the shift to hybrid work. Their study focused on the transition from fully remote or onsite work models to hybrid arrangements, which combine elements of both. This shift reflects a new work paradigm aimed at balancing flexibility with in-person interactions, adapting to evolving workforce needs and preferences after COVID-19.

Marek, K. et al. (2021) explored the impacts of home office on aspects of software development. They found that communication between team members was positively affected, with performance remaining stable or improving. The researchers also provided insights into the Requirements Engineering. The

integration of product owners and stakeholders had improved, while reporting had no impact on the product backlog and vision and confirming that the pace and quality of work remained consistent despite the shift to remote work.

Productivity:

Bezerra, C. et al. (2021) examined changes in work routines and their effects on productivity. Changes in work routine are characterized by an increased workload and the tendency to work beyond standard business hours.

Impacts on work process include notable improvements in productivity and enhanced positive collaboration among team members, suggesting that the adjustments in work practices have led to more effective and cooperative work environments.

Ozkan et al. (2022) discussed how remote work has led to notable improvements in productivity. They highlight that the efficiency of meetings has increased due to better use of digital tools and platforms. Additionally, employees have saved time by eliminating the need for commuting, which has contributed to a more agile and flexible work environment. This increased agility enables quicker responses to changes and enhances overall productivity.

Ågren et al. (2022) focused on key agile practices and their impact on productivity. They explore the challenges encountered by practitioners while implementing these practices and emphasized to address these problems to enhance productivity, and communication within teams. Additionally, the study examines that optimizing agile practices improved the frequency and effectiveness of meetings, contributing to overall better performance in agile environments.

Da Silva, R. M. et al. (2023) discussed the effects of recent work changes on various soft skills. Positive impacts include improvements in adaptability, empathy, and continuous learning, reflecting enhanced personal and professional development in these areas. Negative impacts are observed in reduced motivation and emotional resilience, indicating challenges in maintaining these aspects of soft skills amidst changing work conditions.

Demand on Cloud Solutions:

Schmidtner, M. et al. (2021) emphasized a growing demand for cloud solutions, specifically cloud storage, which facilitates enhanced collaboration among teams. Additionally, the researchers identified the importance of increased flexibility in modern work environments, highlighting the critical role of video conferencing tools. The study also focused on resilience and adaptability, noting the smooth transition to home office setups and the rise in mobile hardware usage.

Mitev, Y. R., & Dimitrov, D. I. (2021) analyzed the surge in demand for cloud applications and public cloud hosting driven by accelerated digitalization. Their research found significant impacts on corporate business, noting that companies are under pressure to hasten their digital transformation efforts to remain

competitive and survive in the evolving market landscape. The increased reliance on cloud solutions highlights the critical role of digitalization in modern business strategies.

Requirements Engineering:

Qahtani, A. M. (2022) discussed significant changes in the requirements elicitation process. The study highlighted an increased number of requirements being collected remotely and a reduced time for requirements analysis.

Additionally, the researchers noted impacts on human resources including a reduction in system analysts allocated at client sites and a shift to remote work for system analysts at the vendor's site.

Russo, D. et al. (2021) discussed that dedicating less time to bug fixing and meetings can significantly improve productivity. Instead, allocating more time to thorough testing and comprehensive documentation leads to better software quality and smoother project progression.

The research also highlights that proper requirements engineering practices streamline the development workflow, reducing the need for extensive bug fixes and frequent meetings, ultimately allowing teams to focus on creating well-tested and well-documented software.

Griffin, L. (2021) explored methods to enhance efficiency in requirements engineering by decreasing waste during requirements gathering and backlog refinement. The study underscored the importance of adapting Scrum practices to suit remote work environments, ensuring that teams can maintain productivity and clarity in their workflows.

Impacts on Corporate Business:

Kettunen, P. et al. (2021) outlined both the positive and negative effects observed in the corporate sector. Positive impacts include an increase in business activities and enhanced digitalization efforts, as companies adapted to new technological demands and opportunities.

Negative impacts are also noted, such as declining business in certain sectors, difficulties in cooperation, impeded development processes, and layoffs. Additionally, there was a reduction in work hours for some employees. The study also highlights impacts with varied degrees, such as the increased prevalence of remote working and the adoption of new working methods, which have had mixed outcomes across different industries and organizations.

Team Management:

Nolan et al. (2021) described how management reports were adapted to address the COVID-19 situation, reflecting the new challenges and changes. They note a shift towards informal progress tracking methods to keep up with evolving team dynamics. Additionally, there was an increased need for videoconferencing tools to facilitate communication and collaboration during this period.

Butt et al. (2021) highlighted several negative impacts experienced during the transition to work in home office. They observed a decline in agile methodology, challenges in coordination, increased costs, and time inefficiencies. Additionally, there were decreases in work satisfaction and difficulties in managing client meetings effectively.

The impacts described above have emerged from the SLR. As a summary, these impacts are presented in the following table. This table presents the impacts along with their names. Each impact is assigned an ID, such as Ix:.

Name of Impact	ID
Home Office	I1
Productivity	I2
Demand on Cloud Solutions	I3
Requirements Engineering	I4
Impacts on Corporate Business	I5
Team Management	I6

Table 27 – Mapping of Impacts of COVID-19 on software development projects

5.3.2 Challenges During COVID-19 on Software Development Projects

The challenges of COVID-19 on software development projects (SLR_RQ1.2) are discussed in this chapter, drawing from the scientific papers reviewed in the SLR. Many dimensions of these challenges were uncovered in the analysis. In this chapter, we will explore what these challenges are. The challenges are presented in tabular form below. This table organizes the challenges by topics and mapping each challenge to individual researchers with references:

Topics	Challenges	References
Adapting to Remote Work	Adjusting communication strategies for home office	Neumann, M. et al. (2022)
	Balancing between private and professional life	Da Silva, R. M. et al. (2023)
	Understanding, and reacting to increasing requirements	Qahtani (2022)
	Ensuring effective communication, and team cohesion	Bezerra, C. I. et al. (2020)
	Communication and technical challenges	Neto et al. (2021)
	Balancing individual preferences	De Souza Santos et al. (2024)
	Maintaining workflow efficiency in digital formats	Marek, K. et al. (2021)
	Integrating new hires	Nolan et al. (2021)
	Conducting Daily Scrum meetings	Griffin (2021)
	Social isolation in teams	Juárez-Ramírez et al. (2022)
Navigating Budget Constraints	Budget freezes or decreases	Mitev and Dimitrov (2021)
	Cost of projects increased	Butt et al. (2021)
Collaboration and Management	Coordinating efforts and sharing information effectively across different locations	Müller et al. (2023)
	Reinforcement of communication tools to improve traceability and efficiency	Neves de Souza et al. (2023)
	Difficulties in communication and collaboration	Hooshyar et al. (2023)
	Maintaining effective communication and collaboration in home office	Russo et al. (2021)
	Decreased productivity due to lack of non-verbal cues	Ozkan et al. (2022)
Work-Life Balance	Managing work-life balance due to increased workload	Bezerra et al. (2021)
Remote Work on Development	Managing development tasks and coordinating efforts remotely	Ma et al. (2022)
Business	Cooperation difficulties in the business	Kettunen et al. (2021)
Digital Transition on Well-Being	Decrease in productivity due to digital communication resulted in increased stress and decreased motivation,	Ågren et al. (2022)

Table 28: Challenges During COVID-19 in Software Projects According to the SLR

In this section, each topic from the table will be discussed in detail. The explanations will provide an understanding of the key challenges of each topic. This detailed overview aims to clarify the significance of the topics listed.

Adapting to Remote Work:

Neumann et al. (2022) discussed the integration of remote work, focusing on changes in communication dynamics and adjustments in agile practices. The shift to remote work has significantly altered how team members communicate,

leading to a greater dependence on digital tools and asynchronous methods. To maintain productivity and team cohesion, agile practices were adapted to the remote environment, emphasizing flexible workflows and regular virtual check-ins. The study has underscored the need to adjust communication strategies and agile methodologies to support remote teams effectively and ensure sustained performance.

Da Silva et al. (2023) emphasized the necessity for developers to swiftly adapt to the dynamics of remote work. They highlighted the importance of managing uncertainties, honing self-management and organizational skills, and maintaining flexibility to ensure productivity. Developers also needed to balance personal and professional spheres effectively, enhance their communication skills, and proficiently use virtual collaboration tools. The study has underscored that successful remote work hinges on teamwork and the ability to navigate these new challenges to achieve project success.

Qahtani (2022) has examined the challenges posed by remote work on development teams. The study has highlighted complications in communication among team members, which can lead to difficulties in understanding and executing customer requirements. Additionally, remote work has introduced increased demands during the requirements elicitation process and has impacted human resources management. These issues underscored the need for improved strategies and tools to address the complexities of remote communication and maintain effective project outcomes.

Bezerra et al. (2020) explored the challenges and enhancements associated with remote work. They identified key difficulties such as maintaining effective communication, ensuring team cohesion, and managing work-life balance. However, the study has also highlighted several enhancements that can improve remote work experiences, including the adoption of advanced digital tools, flexible work arrangements, and the development of new strategies for collaboration. The authors emphasized the need for organizations to address these challenges while leveraging technological advancements to enhance remote work practices.

Neto et al. (2021) addressed the communication and technical challenges in the home office work. They noted that remote work can create communication gaps and misunderstandings among team members, which can negatively affect productivity and project outcomes. Additionally, technical challenges such as limited access to essential hardware, software, or data centers impeded development progress and impacted the quality of work.

De Souza Santos et al. (2024) highlighted the challenges of balancing individual preferences, team dynamics, and project requirements in hybrid work arrangements. They argued that achieving this balance is crucial for maintaining productivity and ensuring the well-being of team members. The study has emphasized that effectively managing these factors can enhance the overall

success of hybrid work models and contribute to a more harmonious and efficient work environment.

Marek et al. (2021) discussed several challenges of work in home office, including the absence of office communication, which impacts team interactions and project management. They highlighted the need to convert physical tools, such as task boards, into digital formats to maintain workflow efficiency. Engaging and involving stakeholders in a remote setting has also become more challenging. The authors stressed the importance of establishing effective training and coaching programs for agile methodologies and noted that onboarding new employees are complicated in a remote environment.

Nolan et al. (2021) addressed the complexities of onboarding new employees in a remote environment. They highlighted that traditional onboarding processes were significantly challenged when conducted remotely, with difficulties in integrating new hires into the team culture and ensuring they receive adequate support and training. The study has emphasized the need for well-structured virtual onboarding programs that effectively address these challenges.

Griffin (2021) has explored the challenges of conducting Daily Scrum meetings in a remote setting. Key issues identified include maintaining adherence to the 15-minute timebox, managing distractions, and addressing fatigue that arises from the absence of in-person interactions. The study has highlighted the need for strategies to effectively navigate these challenges and ensure that remote Daily Scrums remain productive and efficient.

Juárez-Ramírez et al. (2022) explored the challenges such as social isolation and the extensive use of technology. They highlighted how remote work has led to feelings of isolation due to reduced personal interactions and noted the increased reliance on technology.

Navigating Budget Constraints:

Mitev and Dimitrov (2021) examined how organizations navigated budget constraints. They found that budget freezes or decreases had a significant impact, prompting companies to prioritize infrastructure upgrades more strategically. The adoption of remote working became more prevalent as a cost-saving measure, which in turn necessitated processes refinement to ensure operational efficiency.

Butt et al. (2021) found that the pandemic created significant issues for team coordination, as remote work disrupted established workflows and communication channels. Furthermore, the cost of projects increased during the transition to work from home, due to the need for additional technology and resources to support remote operations. These challenges highlighted the financial strain on organizations and the need for strategic adjustments to manage costs effectively while maintaining.

Collaboration and Management:

Müller et al. (2023) investigated trust issues as a major challenge, as remote interactions often led to difficulties in building and maintaining trust among team members. The study also highlighted collaboration difficulties, with teams facing obstacles in coordinating efforts and sharing information effectively across different locations. Additionally, they noted various management challenges that arose when leading distributed teams, including issues with oversight, alignment, and maintaining team cohesion.

Neves de Souza et al. (2023) examined that adapting communication processes and tools for both synchronous and asynchronous communication was essential for effective collaboration. The study noted that the increased workload due to remote work had a significant impact on team dynamics and productivity. Furthermore, they highlighted the need for adjustments to address emerging problems and the reinforcement of communication tools to improve traceability and overall effectiveness.

Hooshyar et al. (2023) found that organizations faced difficulties in communication and collaboration, struggling to adapt to remote work setups while maintaining team cohesion and productivity. Managing project timelines and deadlines also proved challenging under these conditions.

Russo et al. (2021) examined the challenges of maintaining effective communication and collaboration in remote work settings. Their study revealed that many employees struggled to achieve a satisfactory work-life balance, which had potential repercussions on team dynamics and project timelines. These findings highlighted the complexities involved in managing remote teams and emphasized the need for strategies to improve communication, support work-life balance, and minimize disruptions to both team performance and project schedules.

Ozkan et al. (2022) identified difficulties in coordination and decreased productivity as significant challenges faced by leaders. The study also highlighted the struggle to convey non-verbal cues effectively in virtual settings, which impacted communication and overall team performance.

Work-Life Balance:

Bezerra et al. (2021) investigated how increased workload and changes in work routines posed significant challenges for employees. They found that managing work-life balance grew more difficult, leading to notable effects on psychological well-being, such as insomnia and additional childcare responsibilities.

Remote Work on Development:

Ma et al. (2022) found that development efficiency was notably reduced, leading to blocked development processes and delayed development plans. These issues highlighted the challenges faced in managing development tasks and

coordinating efforts remotely, underscoring the need for improved strategies to enhance efficiency and streamline development processes.

Businesses:

Kettunen et al. (2021) reported a declining business environment that led to cooperation difficulties. These difficulties resulted in impeded development and contributed to layoffs. The study highlighted the severe impact of these issues on organizational performance and emphasized the need for effective management strategies to address collaboration barriers and mitigate negative effects on development and employment.

Digital Transition on Well-Being:

Ågren et al. (2022) observed that the shift to digital communication resulted in increased stress and decreased motivation among employees. They also noted that hybrid meetings created challenges, adversely affecting practitioners' well-being and productivity. The study emphasized the difficulties of adapting to new communication methods and underscored the importance of developing strategies to improve employee well-being and boost effectiveness in hybrid work settings.

The challenges outlined above have been identified through the SLR. They are summarized in the table below. This table shows the challenges' names. Each challenge has been assigned an ID, such as Cx:

Name of Challenges	ID
Adopting to Home Office	C1
Collaboration and Management	C2
Work-Life Balance	C3
Navigating Budget Constraints	C4
Remote Work on Development	C5
Business	C6
Digital Transition on Well-Being	C7

Table 29 – Mapping of Challenges of COVID-19 on software development projects

5.3.3 Recommendations for Software Development Projects

The recommendations for software development projects post-COVID-19 (SLR_RQ1.3) are discussed in this chapter, drawing from the scientific papers that were reviewed in the SLR. The recommendations are outlined in the table below, which organizes the challenges by topics and links each recommendation to specific researchers with corresponding references.

Recommendations for Software Development Projects		References
Adapting Agile Practices	Adapt agile practices and roles for remote work conditions.	Neumann, M. et al. (2022)
	Adapting agile practices by emphasizing collaborative work modes.	Müller et al. (2023)
	Monitoring team-based outputs and deliverable quality when adapting agile practices to remote work.	Nolan et al. (2021)
Adapting Remote Communication Tools		Qahtani (2022)
Improving Development Process Transparency		Neves de Souza et al. (2023)
Short Breaks and Clearly Separating Work Time from Personal and Family Time		Neto et al. (2021)
Adaptation, Communication, and Collaboration		Hooshyar et al. (2023)
Future-Proofing for Business Continuity		Schmidtner et al. (2021)
Asynchronous Scrums and Unified Backlogs for Efficiency		Griffin (2021)
Limiting Meetings to Enhance Well-Being		Ågren et al. (2022)

Table 30: Recommendations for Software Development Projects According to the SLR

This section will delve into each topic from the table. It offers detailed explanations to help understand the key recommendations. The purpose of this overview is to clarify the importance of the topics discussed.

Adapting Agile Practices:

Based on the findings of Neumann et al. (2022), it is recommended that organizations adapt agile practices and roles to fit remote work conditions. Enhancing communication objectivity is crucial to overcome the challenges of reduced social exchange among team members. Additionally, it is important to prepare for increased remote work and the growing use of digital tools in the future. Implementing these adaptations will help maintain the effectiveness of agile methodologies and support sustained productivity and team cohesion in dynamic work environments.

Müller et al. (2023) recommended on adapting agile practices by emphasizing agile and collaborative working modes. They highlighted the importance of fostering trust and self-responsibility among team members and transferring decision-making power to the teams themselves. Their study underscored that these approaches were crucial for enhancing team effectiveness and agility, particularly in dynamic and remote work environments.

Drawing from the findings of Nolan et al. (2021), it is recommended that organizations carefully monitor the outputs and quality of deliverables on a

team-basis when adapting agile methodologies to remote work settings. This close tracking is essential to ensure the effectiveness of agile practices and to maintain high standards of work despite the challenges posed by remote environments.

Adopting Remote Communication Tools:

It is recommended to adopt remote communication tools and agile development approaches to effectively collect and analyze requirements, as suggested by Qahtani (2022). Integrating these tools and methods is crucial for navigating the challenges of remote work and ensuring efficient requirement gathering and analysis, especially in rapidly changing environments.

Improving Development Process Transparency:

It is advised to enhance development process transparency by implementing clear identification of activities and employing suitable tools or processes for tracking team members' work, as recommended by Neves de Souza et al. (2023). Organizations should establish reporting channels for daily tasks, schedule regular individual check-ins, and set specific online availability times for team members. Additionally, efforts should be made to support introverted developers in communicating more effectively and to overcome communication barriers through structured reporting meetings and group communication channels. These strategies will promote better transparency and collaboration within development teams.

Short Breaks and Clearly Separating Work Time from Personal and Family Time:

It is recommended to incorporate short breaks throughout the workday and to clearly separate work time from personal and family time, as highlighted by Neto et al. (2021). Implementing more small breaks can enhance overall productivity and well-being. Additionally, defining clear boundaries between work hours.

Adaptation, Communication, and Collaboration:

Organizations should embrace adaptation to new working conditions and communication tools, and prioritize strong collaboration practices, as highlighted by Hooshyar et al. (2023). These steps are vital for overcoming challenges and upholding high standards of work performance.

Future-Proofing for Business Continuity:

It is recommended to implement flexible working arrangements, utilize digital tools for remote collaboration, and prepare for future disruptions to ensure business continuity, as suggested by Schmidtner et al. (2021). These measures will help organizations remain resilient and maintain operational stability in the face of unforeseen challenges.

Asynchronous Scrums and Unified Backlogs for Efficiency:

It is recommended to utilize asynchronous Daily Scrum updates to save time and accommodate different time zones, as explored by Griffin (2021). Additionally, merging backlogs is advised to enhance backlog refinement processes. These strategies are aimed at improving overall efficiency and effectiveness in managing remote teams and their tasks.

Limiting Meetings to Enhance Well-Being:

It is beneficial for companies to limit meetings to support practitioners' well-being, as suggested by Ågren et al. (2022). Reducing the frequency of meetings can help alleviate stress and improve overall work-life balance for employees.

The recommendations identified through the SLR are summarized in the table below. This table lists the recommendations along with their names. Each challenge has been assigned an ID, such as Rx:

Name of Recommendations	ID
Adapting Agile Practices	R1
Implementing Training Programs	R2
Adopting Remote Communication Tools	R3
Improving Development Process Transparency	R4
Corporate Support for Remote Work	R5
Short Breaks and Clearly Separating Work Time from Personal and Family Time	R6
Adaptation, Communication, and Collaboration	R7
Future-Proofing for Business Continuity	R8
Enhancing Organizational Agility to Quickly Adapt to Change	R9
Asynchronous Scrums and Unified Backlogs for Efficiency	R10
Limiting Meetings to Enhance Well-Being	R11

Table 31 – Mapping of Recommendations of COVID-19 on software development projects

5.4   Summary

The protocol was established following the guidelines provided by Kitchenham and Charters (2007). This protocol minimized potential researcher bias and included all information by extracting data from the scientific papers, encompassing the data used to address the defined research questions. The SLR_RQ1 focused on the current state of research regarding the impact of COVID-19 on software development and IT projects. In the figure below, the findings have been systematically categorized into three main thematic areas: Impacts, Challenges, and Recommendations. Each category has been assigned specific IDs for clarity and organization.

Impacts are identified with **Ix** codes, such as I1, I2, I3, etc., representing the various ways in which the COVID-19 pandemic has affected software development and IT projects. (Addressing SLR_RQ1.1)

Challenges are denoted with **Cx** codes, including C1, C2, C3, etc., which specify the difficulties and obstacles encountered due to the pandemic. (Addressing SLR_RQ1.2)

Recommendations are marked with **Rx** codes, such as R1, R2, R3, and so forth, representing the suggested actions and strategies proposed to address the identified impacts and challenges. (Addressing SLR_RQ1.3)
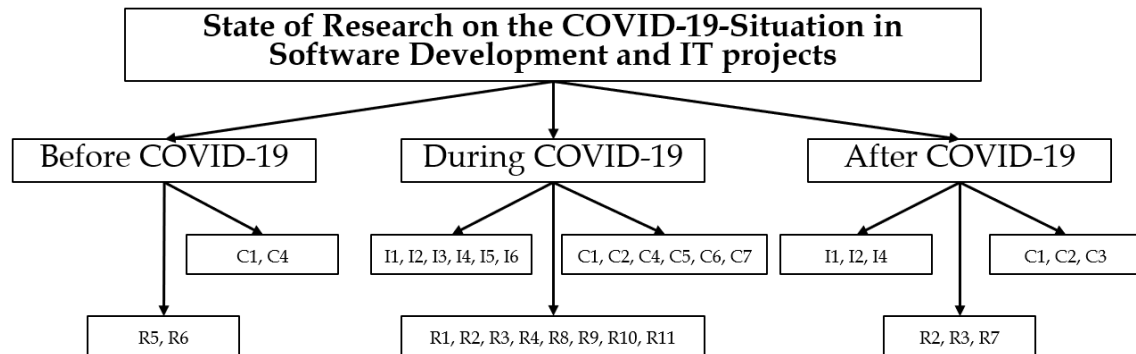

Figure 14: State of research on the COVID-19-situation in software development and IT projects

The mappings of these Impacts, Challenges, and Recommendations can be found in the Appendix of the spreadsheet titled **"SLR_3_Summary.xlsx"**, where the organization and relationships of each item within these categories have been detailed.

In the tables provided below, the mapping of Impacts (I), Challenges (C), and Recommendations (R) can be examined. Six categories of impacts were identified in the SLR, all of these were observed during the COVID-19 pandemic. These thematic areas have been identified as key topics and will serve as a guideline for conducting semi-structured interviews:

- **Home Office (I1):** This theme addresses the effects and adjustments related to the shift towards remote work during the pandemic.

- **Productivity (I2):** This area examines changes in productivity levels and factors influencing performance in a remote or altered work environment.

- **Demand on Cloud Solutions (I3):** This theme explores the increased reliance on cloud technologies and solutions prompted by the pandemic.

- **Requirements Engineering (I4):** This aspect focuses on how the requirements engineering processes have been impacted and adapted due to COVID-19.

- **Impacts on Corporate Business (I5):** This theme evaluates the broader effects of the pandemic on corporate business operations and strategies.

- **Team Management (I6):** This area investigates how team management practices and challenges have evolved during the pandemic.

The SLR identified the following seven distinct categories of challenges:

- Adapting to Remote Work (C1)
- Navigating Budget Constraints (C2)
- Collaboration and Management (C3)
- Work-Life Balance (C4)
- Remote Work on Development (C5)
- Businesses (C6)
- Digital Transition on Well-Being (C7)

Eleven categories of recommendations were highlighted in the SLR:

- Adapting Agile Practices (R1)
- Implementing Training Programs (R2)
- Adopting Remote Communication Tools (R3)
- Improving Development Process Transparency (R4)
- Corporate Support for Remote Work (R5)
- Short Breaks and Clearly Separating Work Time from Personal and Family Time (R6)
- Adaptation, Communication, and Collaboration (R7)
- Future-Proofing for Business Continuity (R8)
- Enhancing Organizational Agility to Quickly Adapt to Change (R9)
- Asynchronous Scrums and Unified Backlogs for Efficiency (R10)
- Limiting Meetings to Enhance Well-Being (R11)

6   Semi-Structured Interviews based on Mayring

This chapter focuses on the conduct of interviews, the analysis of transcripts using MAXQDA Analytics Pro, and the examination of the information gathered in the research field of lasting impacts of COVID-19 on software development projects in the public sector. It ensures a systematic and comprehensive analysis of the data collected, based on Mayring's approach. The following figure provides an overview of the chapter and its contents.
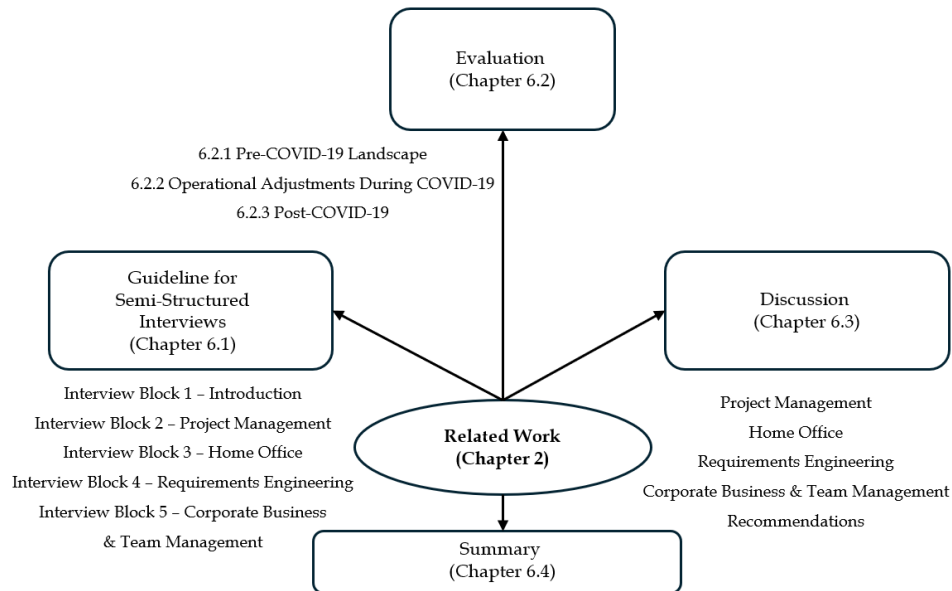
Figure 16: Overview of Chapter 6

6.1   Guideline for Semi-Structured Interviews

The interview situation was a novel experience for both parties involved. To effectively navigate this scenario, the interviews were conducted using a guideline-based approach. This guideline played an important role in ensuring that the focus remained consistently on predefined thematic areas in the topic of this master thesis.

These thematic areas were meticulously developed through a Systematic Literature Review, providing a structured and comprehensive framework for the interviews. The guideline also helped establish the overall framework of the interviews. Within these thematic areas, questions were posed according to principles of objectivity to avoid influencing the interviewee's responses. The guideline was divided into five blocks:
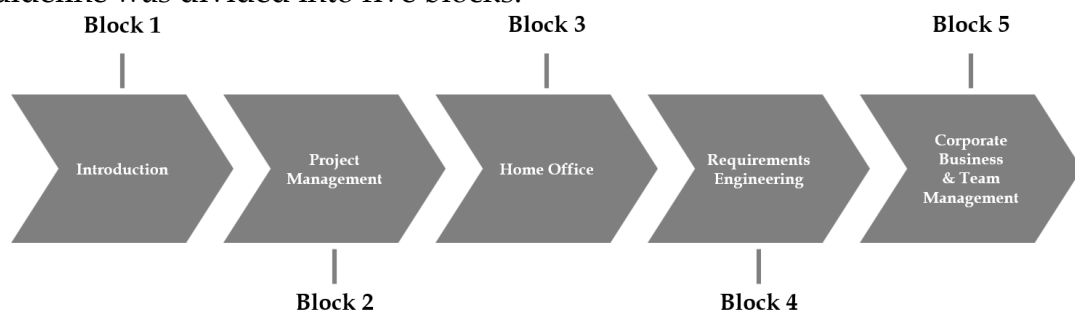
Figure 5−7: Guideline for Semi-Structured Interviews

Block 1 – Introduction:

In this block, the conversation began with a greeting and introduction. The interviewee was asked to share information about their role within their organization. To ensure that each interviewee was an expert in their field, the following questions were asked:

- How old are you?

- What is your highest level of completed education?

- What is your current position?

- Is it a managerial position?

- How long have you been in this profession?

- How long have you been working in public sector?

- What is the size of the projects you have worked on**?**

- How many projects have you been involved in?

Block 2 – Project Management:

The scope of the first block was concluded with the context of the COVID-19 lockdown in Austria, which began on March 16, 2020, when comprehensive restrictions were enforced. Here, the interviewee had the freedom to discuss topics related to software development projects and project management. The interviewee was then asked:

- "How did your organization respond to the COVID-19 situation in a project management manner?"

Block 3 – Home Office:

- This block focused on various aspects of working from home, such as productivity, work efficiency, and the use of collaboration tools, included the cloud tools.

Block 4 – Requirements Engineering:

- The topic of *Requirements Engineering* was examined in depth. To ensure clarity, an introductory definition was provided:

  o "Requirements Engineering, in the classical sense, refers to the systematic process of eliciting, analyzing, and managing requirements for a system or software product."

- The interviewee was then asked to share their experiences by addressing the question:

  o "What new challenges in Requirements Engineering have arisen due to the pandemic, and how have these been managed?"

Block 5 – Corporate Business and Team Management:

- In this final block, the discussion focused on the organization's *Corporate Business* and *Team Management in a software development manner*. An introduction was provided to help the interviewee recall relevant experiences:

    o "We will examine how the pandemic has impacted your company's business goals and strategies. We are particularly interested in how priorities and the company structure have changed, and what long-term adjustments have been made?"

6.2   Evaluation

This chapter focuses on presenting the findings of the Qualitative Content Analysis in *MAXQDA*. To illustrate this, an example for the code "Home Office before COVID-19" is provided demonstrating how the statements of the interviewees were segmented and coded within the transcripts. After coding the segments in the interview transcripts, a summary for each interviewee based on their statements was created. The following table provides an example for the code "Home Office" before COVID-19. The table includes following information:

- Reference: The segments from the transcripts are referenced:

    (<Transcript Name>: <from N° of Paragraph> - <to N° of Paragraph>)

- Segment: The segments from the transcripts are cited.

- Summary: The summary for the code "Home Office" each person.

Pre-COVID-19 Landscape> Home Office		
Reference	**Segment**	**Summary**
P1_EN: 14 - 14	There were already a handful of colleagues who were allowed to work from home.	Before COVID-19, home office was very limited and online meetings were not considered, as in-person attendance was the norm.
P1_EN: 22 - 22	Before Covid, we always met in person, always without exception. Holding an appointment online would have been rejected. We always did it on site.	
P1_EN: 28 - 28	Very limited yes, officially no.	
P2_EN: 16 - 16	We didn't have that before the pandemic.	Before the pandemic, working from home was not an option.
P3_EN: 38 - 38	in my business area, there was absolutely nothing like that.	Before the pandemic, working from home was not an option.
P4_EN: 23 - 23	Before Covid, only a certain group of people had the option of working from home, and it was only set up as a project to gain experience of what it means to work from home. But there were no plans to roll it out on a large scale.	Before COVID, working from home was limited to a select group as a pilot project, with no plans for widespread implementation.

Table 32 – Example of Coding and Summarizing of Interviewee Statements in MAXQDA

In the following subsections, the findings are categorized according to the dimensions of the interview guideline. 6.2.1 presents the findings from the Pre-COVID-19 Landscape. 6.2.2 discusses the findings related to Operational Adjustments During COVID-19. 6.2.3 highlights the findings concerning Post-COVID-19.

6.2.1   Pre-COVID-19 Landscape

This subsection provides information on how a public sector organization worked on its software development projects before the pandemic. This figure graphically represents the codes and subcodes created in MAXQDA for the Pre-COVID-19 Landscape:
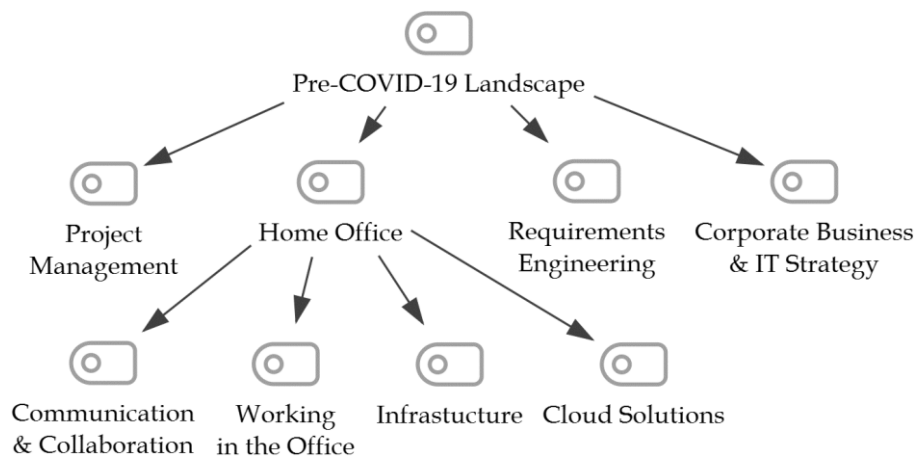
Figure 15: Pre-COVID-19 Landscape MAXMap

Interview Block 2 – Project Management:

For managing software development projects, a ticketing system, Jira, was already in use. In this system, the requirements were prioritized by application management or IT demand management and were assigned to releases.

Additionally, since the software development projects were only developed by external software vendors, it was important to understand the complexity of the developments. To this end, a total sum of story points was assigned to each development.

As reported by the interviewees, a go-live occurs after every 6 weeks of development. Concurrently with the development phase, the analysis phase for the following release runs in parallel.

Interview Block 3 – Home Office:

Before the onset of the COVID-19 pandemic, the work environment was distinctly different from what many have experienced in recent times. The concept of working from home was virtually non-existent. Home office arrangements were highly limited, and online meetings were not yet on the radar. In-person attendance was the standard practice, and working from home was restricted in a pilot project with no plans for broader adoption.

In contrast, the office environment was characterized by a high degree of physical presence and traditional work practices. Software suppliers were nearly always on site, reflecting the preference for face-to-face interactions over remote communications. Employees typically had their own offices or shared them with only one or two colleagues, fostering a structured and somewhat private work setting.

Despite advancements in technology, the various administrative tasks still relied heavily on paper, such as applying for a new cell phone. This reliance persisted even with the existence of document management systems, illustrating a blend of old and new practices that defined the pre-pandemic work landscape.

In relation to the topic of home office before COVID-19, several additional themes have emerged, including Communication & Collaboration, Infrastructure, and Cloud Solutions:

Communication & Collaboration: In the pre-COVID-19 era, communication and collaboration were deeply rooted in face-to-face interactions and traditional methods. Software suppliers were nearly always present on-site, emphasizing the importance of in-person engagement for effective collaboration. Meetings with software developer companies and internal teams were conducted only in person.

During these in-person meetings, tools like flipcharts were commonly used to facilitate discussions and brainstorming sessions. Summarizing notes was done manually, often typed out in MS Word documents after the meetings. This approach was standard practice, and while technology like the ticketing system Jira was already in use, its role was somewhat different from the comprehensive online project management tools using in the organization nowadays.

Infrastructure: Before the COVID-19 pandemic, the infrastructure of the workplace was distinctly oriented towards traditional office settings, with a clear directive prohibiting the use of private software and hardware. The anticipation of working in home office was not on the horizon, and as such, the infrastructure was primarily designed to support in-office operations.

The technology landscape was dominated by desktop computers and landline phones, which constituted the core of daily operations. Mobile phones and remote capabilities were reserved mainly for management and specific in-house functions, reflecting a limited approach to mobile and remote access. This infrastructure was well-suited for a work environment where physical presence was the norm, and the need for extensive remote connectivity was minimal.

This focus on office-based infrastructure underscores a time when the concept of working from home was neither anticipated nor supported, shaping a work environment reliant on physical office resources and traditional communication tools.

Cloud solutions: The cloud solutions were still in their nascent stages within the organization. Qlik, a data analytics tool, had been partially introduced before the pandemic, but its implementation was incomplete. The initial efforts to integrate Qlik were intended to modernize data analytics, yet the tool's full potential was not realized at that time. In the aftermath of the pandemic, there was a perception that the organization had regressed to using older data analytics tools.

At the outset, cloud tools were explored on a limited scale as the organization experimented with their potential and effectiveness. These experiments involved only a few departments, which participated in pilot projects to assess the benefits of cloud solutions. This cautious approach reflected a period of exploration and adaptation, as the organization began to understand the role that cloud technologies could play in enhancing operational efficiency. Overall, the use of cloud tools was limited, with only a handful of departments participating in early-stage implementations.

Interview Block 4 – Requirements Engineering:

The presence of a dedicated application manager or IT demand coordinator was crucial in mitigating these challenges. When such roles were filled, the impact of requirements management was notably reduced. However, in the absence of these specialized roles, internal staff frequently assumed the responsibility. They found face-to-face meetings to be considerably more effective than video conferences for addressing and resolving issues related to requirements, highlighting a preference for in-person communication in complex discussions.

In terms of process, the workflow for requirements engineering involved reporting a need, specifying it collaboratively, and subsequently creating a ticket for analysis and implementation with the software service provider. This structured approach ensured that all requirements were meticulously documented and managed.

From the outset, ticketing system, Jira played a central role in documenting and managing requirements. All service providers were involved in this system, which facilitated a structured method for tracking and addressing requirements across various projects. Despite the limitations of the era, the use of these tools laid the groundwork for effective requirements management and collaboration.

Interview Block 5 – Corporate Business and Team Management:

The IT department before pandemic, was part of the "Organization Finance and Human Resources" department. The following figure summarizes the organisation's structure and the role of information technology subdepartment under organization, finance & human resources department:
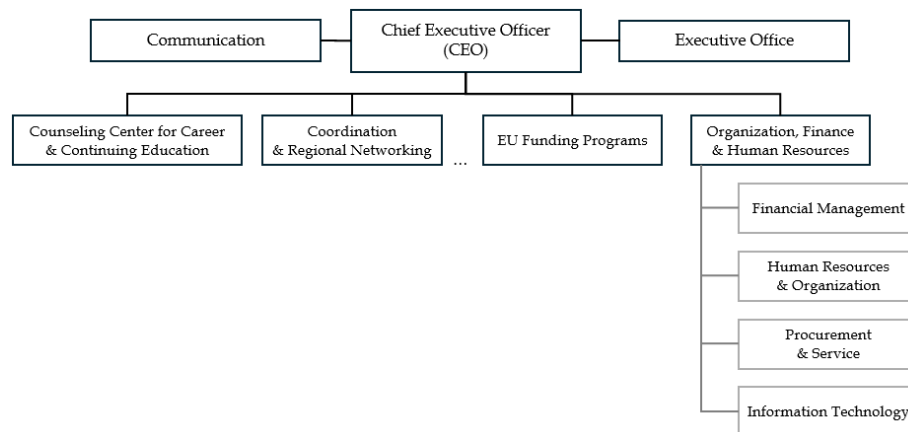
Figure 16: Organizational Chart of the Public Organization (Before COVID-19)

Before the onset of the COVID-19 pandemic, the organization was already strategizing a significant shift towards web applications. The transition towards web applications was part of a broader initiative to leverage technology for better business outcomes. By investing in web-based solutions, the organization aimed to facilitate more efficient data handling and reporting. However, the IT strategy was not clear to all the interviewees, despite their roles within the IT department.

6.2.2 Operational Adjustments During COVID-19

In this subsection, an overview is offered of how software development projects were managed in a public sector organization during the pandemic, contrasting with practices from the pre-pandemic period. The codes and subcodes listed below were generated in MAXQDA:
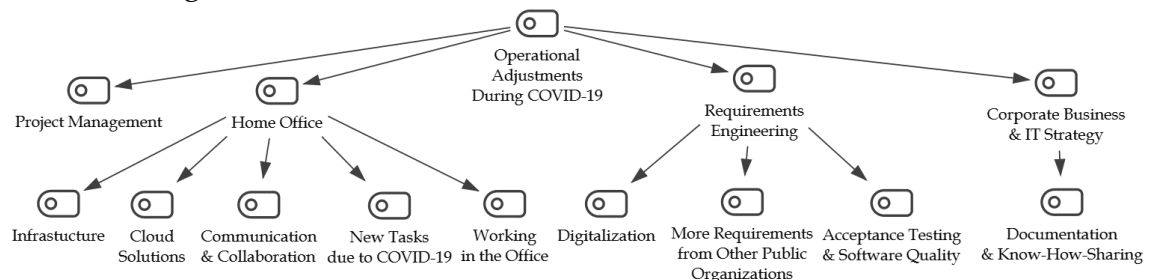
Figure 17: Operational Adjustments During COVID-19 MAXMap

Interview Block 2 – Project Management:

During the COVID-19 pandemic, project management faced unprecedented challenges as organizations scrambled to adjust their schedules and priorities. The need to rapidly develop customer-focused applications led to confusion about their relevance and required adjustments.

Nolan et al. (2021) noted that management reports had to be adapted to reflect the COVID-19 situation, and informal progress tracking became more prevalent. In contrast, in public sector, amid the pandemic, the focus shifted to analyzing essential software requirements and developing critical infrastructure. Although the reporting processes with software providers remained the same,

prioritization became crucial. This difference highlights that while formal reporting adapted to the new circumstances, the core reporting processes, and prioritization strategies had to be reassessed to meet evolving needs.

Projects like Qlik, once a top priority, saw their implementation deferred as the pandemic redefined project goals and priorities.

The shift to digitalization highlighted the need for flexibility. Requirements were broken into smaller, manageable pieces, allowing for quicker fixes and adjustments. This approach enabled rapid deployment of new programs while deferring less urgent initiatives, demonstrating the importance of adaptability in managing projects during a crisis.

Interview Block 3 – Home Office:

Before the lockdown, the organization had opted to stay in the office, but the lockdown on March 16, 2020, made working in home office the primary option. While the necessity for physical office space diminished, occasional in-office meetings remained important for staying connected. Neumann et al. (2022) highlighted the effectiveness of a hybrid work modell to balance flexibility and collaboration. However, this shift also led to a decrease in social exchange, impacting informal communication channels essential for spontaneous idea sharing and problem-solving.

During the time of COVID-19, the transition to home office work was sudden and initially a great challenge, as the work tools needed for working at home had to be purchased and distributed to the employees, and then all of this had to be administered.

Employees soon found working from home to be more efficient due to fewer interruptions and better concentration. The company adapted by allowing three days of remote work and two days in the office as conditions improved. The productivity remained high despite the initial challenges. Neumann et al. (2022) observed that this hybrid model led to stable or increased performance.

Enhanced security measures were implemented to address new risks associated with remote work.

In the context of transitioning to home office work, several key themes have come to the forefront, including Communication & Collaboration, Infrastructure, New Tasks Due to the Pandemic, and Cloud Solutions:

Communication & Collaboration:

During COVID-19, the landscape of Communication & Collaboration underwent a dramatic transformation. As on-site visits became impractical, online meetings quickly became the norm. Software suppliers transitioned to video conferences. Tools like Google Meet, Jitsi, Miro, and OnlyOffice emerged as essential for maintaining effective remote collaboration. According to Bezerra et al. (2020), communication tools were more important for effective communication.

Initially, the software development teams adapted well to these new tools, embracing video conferences and online platforms. The rapid shift to remote work saw a surge in the use of video conferencing tools and mobile phones, which significantly accelerated communication processes. Joint appointments and virtual meetings became crucial for keeping team members aligned and ensuring a consistent level of knowledge.

Requirement analysis and specification were adapted to hybrid and online formats, with Miro boards and Kanban boards replacing physical flipcharts.

Despite the smooth transition, challenges soon emerged. As the use of email and collaboration tools became more widespread, issues with usability and efficiency surfaced. Personnel absences led to task reassignments, which had varying impacts across departments, though application management faced fewer disruptions. Accessibility was affected as immediate in-person clarifications were replaced by virtual meetings or phone calls, introducing delays and disrupting the usual rapid communication flow. Schmidtner et al. (2021) noted that the smooth transition to home office environments also resulted in a significant increase in mobile hardware usage.

The shift to remote communication was also facilitated by long-standing relationships with software service providers, making the transition smoother despite the loss of personal interaction. Previously large in-person meetings were successfully conducted online, with no need to alter existing applications or customer criteria, thanks to the already web-enabled nature of our tools.

Overall, while the shift to remote communication introduced new challenges, the adaptation to video conferencing and online collaboration tools ensured that productivity remained unaffected and that team interactions continued to thrive in a virtual environment.

Infrastructure:

The organization faced a swift and chaotic shift to remote work. Initially, only a few employees had the necessary home office setup with Chromebooks. As remote work demands grew, so did the need for additional equipment like monitors and docking stations. The company quickly procured and distributed these items, adapting infrastructure through trial and error.

The digital department played a crucial role, distributing devices and creating training materials to help employees adjust. Despite challenges with internet stability and varying technical standards, the company transitioned from traditional file servers to open-source and cloud solutions. They outsourced IT systems to a secure data center and provided essential equipment, while scaling applications and adjusting security protocols to ensure smooth remote access.

Internal departments initially used different tools, leading to some duplication, but the company managed to maintain productivity and support through internal helpdesks and ticketing systems. Overall, the company successfully

adapted to remote work, overcoming initial obstacles and ensuring continued operations.

New tasks due to pandemic:

During the COVID-19 pandemic, the company faced a wave of new responsibilities that significantly altered daily operations. The sudden shift to remote work required the rapid procurement and distribution of essential equipment like Chromebooks. This process was not without its challenges; managing the logistics of delivering equipment to employees and handling a surge of additional requests created a complex scenario.

The heightened requirements during this period also impacted the acceptance of new software versions, as resources were diverted to address immediate needs. However, these tasks were temporary, and the company eventually resolved the issues. Despite the challenges, the company successfully adapted to the new demands and maintained operational continuity.

Cloud solutions:

The cloud solutions like OnlyOffice for remote work were rapidly adopted by the organization. Despite initial user frustration with unfamiliar tools, cloud storage became essential. OwnCloud was used for file storage, though some older users stuck with terminal servers. Public cloud solutions were not commonly used in the public sector during COVID-19. In contrast to Mitev and Dimitrov (2021), who noted that the use of public cloud hosting has increased in general. However, there is also an overlap with cloud applications. The researchers pointed out that the demand for cloud applications has significantly increased.

The company moved data to a secure external data center in Austria, balancing cloud and traditional technologies to enhance general data protection regulation (GDPR) and operational readiness. Overall, the pandemic accelerated the shift to cloud-based document storage, initially planned for a longer timeline.

Interview Block 4 – Requirements Engineering:

The requirements engineering faced significant challenges due to a surge in new project demands. The pandemic intensified pre-existing issues with tracking numerous initiatives and maintaining transparency. As digitization efforts like e-signatures and automated workflows stalled, the lack of feasibility discussions hampered their swift implementation.

The shift to working from home also introduced new requirements to adapt workflows and address the absence of in-person customer interactions. Procuring equipment like Chromebooks diverted time and energy from analyzing and reviewing requirements, and testing, although no incidents caused delays. According to Griffin (2021), decreasing waste in requirements gathering and backlog refinement became essential.

The existing ticketing system became more important than before the pandemic, demanding more precise and well-formulated specifications to handle the growing backlog. With the rapid shift to home office, requirements had to be prepared quickly to expand online services. This led to a more iterative development approach, focusing on delivering minimum viable products (MVPs) swiftly. In contrast, Marek et al. (2021) observed that there were no significant impacts on the product backlog and vision, and the pace and quality of work remained undisturbed.

Despite these changes, the approach to requirements engineering remained consistent, with a focus on adapting processes to online formats. The core structures and volume of backlogged tasks stayed steady, though the public sector faced increased demand and adjusted priorities. Overall, the need for swift adaptation became a shared experience across the organization.

In the context of Requirements Engineering, several key aspects have been highlighted. Firstly, the increasing digitalization has led to a surge in the number of requirements that need to be addressed. Additionally, there is a growing demand for requirements stemming from various public organizations. Furthermore, the importance of acceptance testing and software quality has been emphasized as crucial components in ensuring that these requirements are met effectively:

More requirements in digitalization:

During the epidemic, the push for digitalization took on new urgency, though internal projects often took a backseat as departments prioritized their immediate needs and redirected resources to address public sector staffing shortages. Despite this, there was a swift and strategic investment in digitalization and automation to accelerate the digitization of business processes. According to Mitev and Dimitrov (2021), this period saw an accelerated digitalization as companies were pressed to speed up their digital transformation efforts to survive and adapt to the rapidly changing environment.

The pandemic drove a focus on making applications accessible from anywhere, with a particular emphasis on web applications and promoting e-signatures. The primary objective was to ensure business processes could continue effectively without requiring physical presence.

COVID-19 accelerated digitalization efforts, leading to the creation of additional projects that might not have emerged otherwise. Processes were rapidly adapted to support video calls and self-service features, and digital support was enhanced. Even with a partial return to office work, the momentum for digital solutions remained strong, demonstrating the pandemic's profound impact on accelerating the digital transformation of the organization.

More requirements from other public organizations:

The pandemic prompted a significant shift in priorities for both the City of Vienna and our company. Measures to support the unemployed were rapidly rolled out, resulting in an immediate and unplanned focus on external applications rather than internal systems.

The crisis not only accelerated the need for new implementations but also necessitated adjustments to existing rules. Despite the heightened pressure to deploy new features quickly, the challenge was managed effectively by prioritizing tasks.

Acceptance testing & software quality:

The expansion of the custom software, developed in collaboration with an other public party, was well-received during the COVID-19 pandemic, with no complaints about usability or software quality. Acceptance testing transitioned smoothly to virtual meetings with screen sharing, enhancing flexibility. This change allowed for more spontaneous test appointments and location-independent testing, becoming a lasting improvement.

Given the urgent need for rapid implementation, there was a higher tolerance for errors, with the understanding that issues could be revisited and resolved in subsequent iterations. In contrast, Russo et al. (2021) found that there was less time allocated to bug fixing and meetings, indicating a focus on accelerating delivery rather than addressing every issue immediately. This difference highlights how the rapid pace of work during the pandemic led to prioritizing swift implementation over thorough error resolution and extensive discussions.

Despite the accelerated pace, there was sufficient capacity to handle any outages, ensuring that application quality and implementation issues remained unaffected. Consequently, no departments had to shut down due to these challenges.

Interview Block 5 – Corporate Business and Team Management:

According to Kettunen et al. (2021), this transition not only facilitated more business opportunities but also enhanced digitalization efforts, further advancing the company's capabilities in the digital landscape.

While the core focus remained the same, the approach during the pandemic shifted significantly. The digital formats became essential to reach target groups and enhance digitalization efforts. The company prioritized enhancing self-service options for customers and increasing online tasks, thereby reducing reliance on paper-based processes.

Documentation & Know-How-Sharing:

The infrastructure department recognized the critical need for effective documentation and knowledge sharing to support remote work. Numerous how-to guides were developed for setting up phones and VPNs on

Chromebooks, ensuring employees could transition smoothly to working from home.

The pandemic highlighted the importance of knowledge transfer, given the potential for staff absences. To address this, many new how-to guides were created, and external consultants were brought in to provide additional support. Despite the surge in documentation efforts, the overall conditions for documentation remained unchanged, ensuring continuity and accessibility of information. According to Russo et al. (2021), there was a notable increase in the time dedicated to documentation, reflecting the need for more comprehensive and accessible resources to support remote work and maintain operational efficiency.

6.2.3 Post-COVID-19

In this subsection, an overview is provided of the impacts and developments in software development projects within a public sector organization in the post-COVID-19 era. The following codes and subcodes were created in MAXQDA:
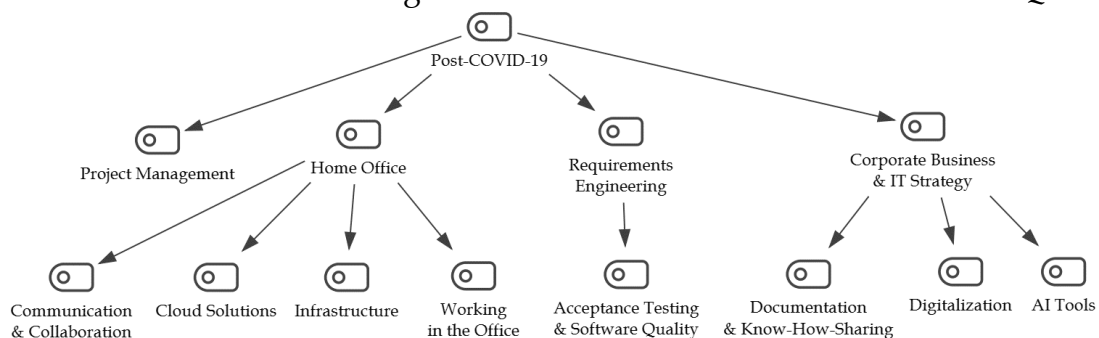
Figure 18: Post-COVID-19 MAXMap

Interview Block 2 – Project Management:

In the post-COVID-19 landscape, project management processes remained largely unchanged, retaining their structured development cycles. Jira continued to serve as the primary tool for managing workflows, which still comprised six weeks of analysis and implementation-testing-go live phases.

However, project management became more precise, with an increased reliance on the ticketing system and improved documentation of task progress. Story points remained an effective measure for gauging the scope and complexity of requirements fulfilled. These refinements ensured that despite the challenges posed by the pandemic, project management retained its efficiency and effectiveness, paving the way for consistent and successful project outcomes.

Interview Block 3 – Home Office:

Before COVID-19, there was no formal company agreement on home office. The pandemic led to the establishment of policies clarifying the distinctions between mobile working and home office.

In the post-COVID-19 era, home office has become the norm, providing flexibility and reducing daily commutes. A standard home office policy has been established in the digital department, with occasional in-office meetings required by management.

The current hybrid model requires employees to work two days in the office and three days from home, managed through a time recording and office booking system. Office rooms are now unassigned and booked by employees as needed each day, further supporting the flexible work environment.

The IT department's policy of two days in the office and up to three days of remote work has proven effective and manageable. The success of remote work during the pandemic highlighted its viability, and the current arrangement offers greater flexibility with the right tools.

In the context of remote work, the following topics have come additionally into focus in the post-COVID-19 era:

Communication & Collaboration:

Communication and collaboration have evolved significantly. Online appointments have become the norm, with meetings typically expected to offer a hybrid option due to established technology and habits. Video conferences have improved flexibility and saved time and costs by eliminating the need for travel. This change has made scheduling more efficient and accelerated progress, as video meetings are quicker to set up and conduct than in-person meetings. According to Bezerra et al. (2021), this shift has not only improved productivity but also fostered positive collaboration among team members, further enhancing overall work efficiency and effectiveness.

The focus on detailed requirements in the ticketing system has enhanced traceability and collaboration, ensuring smoother transitions if team members need to step in. However, while virtual meetings are efficient for routine tasks, the use of collaboration tools has decreased post-COVID. Face-to-face meetings have proven essential for brainstorming and creative processes, as in-person interactions remain superior for dynamic and collaborative activities.

Balancing digital and physical presence is key for effective teamwork. Hybrid meeting formats have become common, balancing in-person and remote participation. This approach allows for greater flexibility, and despite the shift to home office regulations, productivity remains high when management trusts employees to perform effectively remotely. The new communication and collaboration strategies have successfully maintained output quality while adapting to the changing work environment. According to Qahtani (2022), there was also a significant shift to remote work for system analysts at vendor's sites.

Infrastructure:

The digital infrastructure set up during the pandemic remains intact, with Chromebooks and smartphones provided to all employees. This setup ensures the company is prepared for future disruptions and facilitates a smooth transition to remote work when needed. The robust infrastructure supports ongoing productivity and readiness.

Cloud solutions:

The organization has continued to advance its cloud solutions. Most files are now stored in OwnCloud, although some remain on the Terminal Server as the transition away from it is still underway.

As digital workflows become increasingly integral, the organization is adopting Microsoft cloud solutions to boost cross-departmental collaboration, ensure regular and scalable access to data, and support networked working on shared documents. Most employees have embraced these cloud solutions, with only a few still relying on terminal servers.

Interview Block 4 – Requirements Engineering:

The requirements engineering has adapted to new realities. Feasibility discussions with external parties often remain inadequate, and despite each application having a dedicated manager, inter-departmental coordination has suffered, exacerbated by the pandemic.

To address these challenges, there has been a shift towards greater reliance on video conferences and email for requirements engineering. Emphasis has been placed on documenting all requirements and developments in the ticketing system to enhance traceability and visibility.

There is now a greater need for comprehensive documentation in Jira to ensure that tickets are clearly described and actionable. This helps prevent issues when a ticket fails or requires testing by others. Additionally, departments have begun sharing requirements and innovative initiatives directly with software providers, rather than relying solely on the digital team. This improves the collaboration and streamline the requirements process in a more distributed work environment.

Acceptance testing & software quality:

Post-COVID-19, expectations for software performance have tightened, leading to a reduced tolerance for bugs. Testing processes have become more fragmented and time-consuming due to less effective online collaboration and the continued challenges of remote work. Scheduling and coordination have become more complex, making careful planning and thorough documentation in the acceptance process increasingly crucial.

Experiences with acceptance testing varied among interviewees. Older participants preferred in-office testing, finding it more effective and

straightforward. In contrast, younger interviewees reported that organizing test appointments has become more flexible and that the use of video conferencing tools and screen sharing has improved the testing process compared to pre-pandemic times.

Interview Block 5 – Corporate Business and Team Management:

In the wake of COVID-19, the company recognized the urgent need for a clear IT strategy, leading to the establishment of a separate department called digital. This restructuring aimed to address the gaps highlighted by the pandemic and is focused on developing a comprehensive corporate strategy that will guide the digitalization efforts.

The following figure illustrates the restructured hierarchy and reporting lines within the organization after COVID-19. Changes in the organization that are highlighted in green. The organizational chart shows that the digital department gained a more significant role directly after the pandemic. While the Communication Department no longer operates as a unit alongside the CEO:
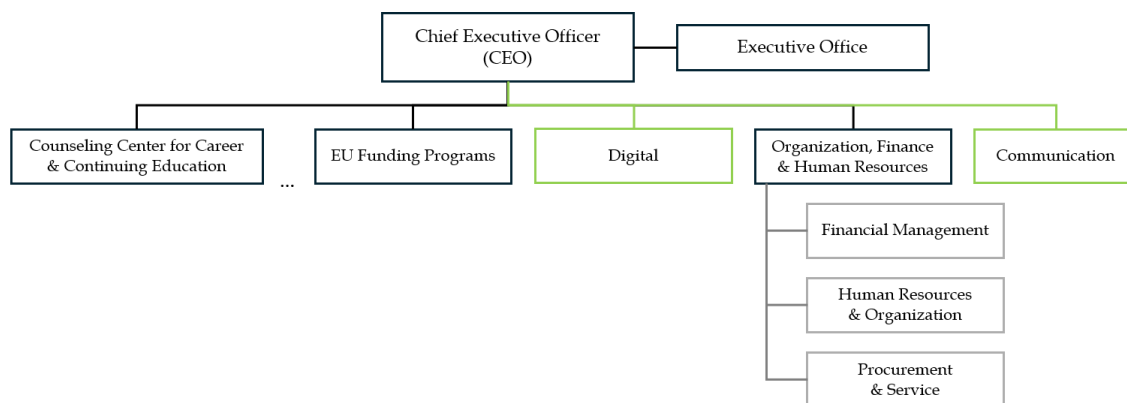
Figure 19: Organizational Chart of the Public Organization (After COVID-19)

The pandemic underscored the absence of a clear digitalization strategy and the critical importance of data security and resource allocation. Consequently, the company is now concentrating on transitioning to cloud-based analysis tools and enhancing data security. The separation of IT into an independent department has increased resources and fostered a more robust approach to digitalization, with no current bottlenecks in implementation.

The experience of the pandemic highlighted the inadequacies of the decentralized approach previously used and emphasized the need for a cross-organizational digitalization concept. This concept, now under development, aims to address data security, IT strategy, and long-term planning comprehensively.

The company's post-pandemic strategy prioritizes detailed documentation and the use of cloud solutions, though the digitization concept is still evolving. IT has become more integrated into all company processes, with increased emphasis on developing self-service tools and cloud-based solutions. The pandemic has

shown the importance of early IT involvement in planning to ensure alignment between systems and business needs, marking a significant shift towards a more strategic and integrated approach to IT within the organization.

In the context of Corporate Business and Team Management, connections have emerged with AI tools, digitalization, and documentation & know-how sharing.

AI Tools:

Although only one interviewee discussed AI tools, it is important to note that a public organization has slated the introduction of AI tools in its roadmap for the near future. The growing emphasis on AI tools and other technologies reflects a broader shift towards IT and process digitization. This move away from paper-based methods aims to enhance flexibility and location independence, with management recognizing the necessity of modern tools for effective operations.

Digitalization:

In the post-COVID-19 era, the company has fully embraced digitization. All procurement processes, whether for hardware or software, are now conducted electronically. External documents require electronic signatures, and internal processes are managed entirely paperless. This shift reflects a heightened focus on the importance of digitization within the company, highlighting a significant transformation in how operations are carried out

Documentation & Know-How-Sharing:

In the wake of COVID-19, the company has significantly enhanced its documentation and know-how sharing practices. The increased need for thorough documentation has led to improvements in the time recording and office booking systems, incorporating features to track remote work and require managerial confirmation. These enhancements are part of ongoing efforts to standardize and streamline processes.

A systematic development of a Wiki has further underscored the importance of comprehensive documentation. This Wiki ensures that crucial knowledge is accessible to multiple users, highlighting how essential effective knowledge sharing and continuity are for organizational success.

While some documentation practices were in place before the pandemic, the shift has brought the focus on comprehensive software documentation, expanding beyond internal purposes. The transition to email requests and the requirement for team leader approval have streamlined internal workflows. However, there is now an increasing need for on-site support and detailed documentation to retain internal know-how and address the higher demand for assistance.

6.3   Discussions

This chapter focuses on a detailed discussion of the study's results, emphasizing the impact of COVID-19 on key themes such as Project Management, Home Office, Requirements Engineering, and Corporate Business and Team

Management. The pandemic has driven significant changes in these areas. This exploration aims to shed light on how these shifts have influenced work and organizational dynamics in the post-pandemic era in software development projects in public sector.

6.3.1 Project Management

In the initial stages, this shift led to a substantial increase in the coordination effort required for internal software projects. Teams had to navigate various internal alignments concerning requirement analyses, schedule test dates, and manage availability issues caused by illnesses. Additionally, arrangements for substitutions during absences due to sickness became more complex and essential.

Planning colleagues' availability became a crucial task during this period, as the spontaneous office visits for project discussions were no longer possible during the lockdown. This required meticulous scheduling and coordination to ensure that all team members were accessible for meetings and collaborative efforts. The inability to drop by a colleague's desk for a quick chat meant that all communications had to be more deliberate and planned.

During the pandemic, software development projects have increasingly adopted Agile. Features are broken down into smaller parts in the backlog, allowing for continuous iterative development. Major developments are often implemented as MVPs. This approach has made tracking easier for both the client and the software supplier. Ågren, P. et al. (2022) emphasize also the importance of focusing on key Agile practices, which has proven essential in adapting to these changes and improving overall project management.

6.3.2 Home Office

In response to the pandemic, a formal home office policy was introduced, providing clear guidelines and expectations for home office. This policy, initially a temporary measure, proved to be highly effective and remained in place even after the pandemic subsided. The continued implementation of this policy reflects the organization's commitment to flexibility and the recognition of the benefits that remote work can offer to both employees and the company.

In the realm of home office, several subtopics have emerged and evolved, especially during the COVID-19 pandemic. These subtopics have also influenced the broader concept of home office practices. The following chapter highlights the key areas of focus, including Communication & Collaboration, Infrastructure, and Cloud Solutions.

The shift to work from home has significantly impacted the digital department, primarily due to the increased reliance on home office arrangements, new tools, and evolving software requirements. This transition necessitated a more

prominent role for the department, which had to adapt swiftly to the new demands and challenges presented by the home office setup.

Communication & Collaboration:

The introduction of video conferencing tools became a cornerstone of daily operations, enabling teams to communicate and collaborate effectively despite the physical distance. According to Schmidtner, M. et al. (2021), who emphasized that video conferencing tools are important for maintaining productivity and connectivity in home office settings.

Although Neves de Souza (2023) reported on using more virtual communication channels, team members in public sector software projects prefer video conferencing tools and email. Before the pandemic, they didn't use video conferencing tools and relied solely on email and in-person meetings.

Setting up new devices for home office use involved a structured approach, ensuring that each employee was properly equipped and trained to use the new tools efficiently. Schmidtner, M. et al. (2021) noted also the increase in mobile hardware usage, highlighting the necessity for employees to adapt quickly to these new technologies to maintain productivity in a remote work environment.

Furthermore, there are tools that were not uniformly implemented during the pandemic, and they are still being used as duplicates.

Infrastructure:

Before the COVID-19 pandemic, all employees worked on desktop computers located in the office. However, as the pandemic forced a transition to work in home office, the organization provided each employee with a smartphone, a Chromebook laptop, and an additional monitor to facilitate their home office setup. This deployment of new equipment was critical to ensure that employees could maintain productivity and stay connected while working remotely.

Cloud Solutions:

The transition to working from home also accelerated the adoption of cloud technologies to support storage and collaboration needs.

Cloud Storage: Cloud storage solutions became integral to the department's operations, allowing for secure and efficient access to necessary files and documents from any location. This shift ensured that all team members could work on shared resources without the limitations imposed by physical storage or in-office servers. Schmidtner, M. et al. (2021) highlighted also that cloud storage facilitates collaboration.

Cloud-based Collaboration Tools: In addition to cloud storage, cloud-based collaboration tools were adopted to enhance communication and teamwork. Mitev, Y. R., & Dimitrov, D. I. (2021) also noted the increased demand for cloud applications.

Shift to Microsoft Cloud Services: The pandemic also prompted a notable shift from open-source services to Microsoft Cloud solutions, particularly in the public sector.

6.3.3   Requirements Engineering

Before the pandemic, requirements were not as precisely formulated and specified as they are after the pandemic. The ticketing system, Jira, has gained increased significance. Requirements are now documented exclusively in Jira, in collaboration with software suppliers. There is now a greater emphasis on thorough documentation in Jira to ensure tickets are clear and actionable, reducing issues with failures or testing. Departments are also sharing requirements and initiatives directly with software providers, improving collaboration and streamlining the process in a more distributed work environment.

The ticketing system gained importance post-pandemic, requiring precise specifications to manage the backlog. The shift to home office led to an iterative development approach focused on swiftly delivering MVPs. After the pandemic, IT demand managers and application managers began creating more tickets compared to the pre-pandemic period, reflecting an increased need for managing and tracking a higher volume of requests and issues. According to Griffin (2021), decreasing waste in requirements gathering and backlog refinement is essential for optimizing these processes to handle the increased ticket volume more efficiently.

The requirements engineering became more stressful with the onset of the lockdown. The transition to remote work was one significant factor, with some interviewees noting that they also had to handle equipment procurement as an additional task. Stress levels increased as priorities were frequently adjusted at the beginning of the lockdown. However, the stress level in Requirements Engineering has decreased since the pandemic. Furthermore, the demand for processing more tickets within a shorter timeframe grew, as new COVID-related requirements in software projects needed to be documented, analyzed, and implemented as quickly as possible.

Acceptance testing & software quality:

Acceptance of new software versions was affected by acceptance tests conducted from home, as the previously used testing methods could no longer be performed on-site. This led to delays in acceptance tests for some software projects.

After the COVID-19 phase, more extensive acceptance tests are conducted with team members meeting in the office, while smaller requirements can be tested remotely from home.

6.3.4 Corporate Business and Team Management

The pandemic exposed the flaws of the previous decentralized approach, highlighting the need for a unified digitalization strategy. This new strategy, still in development, focuses on data security, IT strategy, and long-term planning. Post-pandemic, the organization emphasizes detailed documentation and cloud solutions. Early IT involvement in planning has become important, aligning systems with business needs and marking a shift towards a more strategic IT approach.

Restructuring of the Organization:

To better respond to new situations, the organizational structure was adjusted, with notable changes involving the IT department. The reviewed public organization underwent a major restructuring, elevating the IT division to a standalone business unit directly under the managing director and called digital. This change emphasized the importance of security and aimed to accelerate the planning of digitalization strategy.

This restructuring and shift in focus enabled the company to adapt swiftly to the challenges posed by the pandemic, ensuring continued progress in its digitalization strategy and improving overall operational efficiency. These changes were aimed at enhancing agility and efficiency within the organization:

The "Digital" Department: The newly named digital department has assumed a more prominent role within the organization. It has been assigned a new position in the organizational chart, reflecting its increased importance.

Direct Access to Management: The leadership of the digital department now has direct access to the executive management. This restructuring has shortened decision-making pathways, enabling quicker responses to emerging situations compared to the pre-COVID era.

Enhanced Digital Strategy: With the digital department's elevated role, the digital strategy has become more significant and prioritized within the organization. This shift underscores the critical importance of digital transformation and technological advancement in the post-pandemic landscape.

The following figure illustrates the organizational changes affecting the IT/digital department. Before the pandemic, the IT department was part of the "Organization, Finance & Human Resources" division and had direct contact with the CEO (marked in green in the figure). The IT manager was in contact with the head of the "Organization, Finance & Human Resources" department

(marked in orange in the figure). After the pandemic, the IT department was renamed to digital and now has direct contact with the CEO. The Head of Digital is involved from the very beginning in development projects.
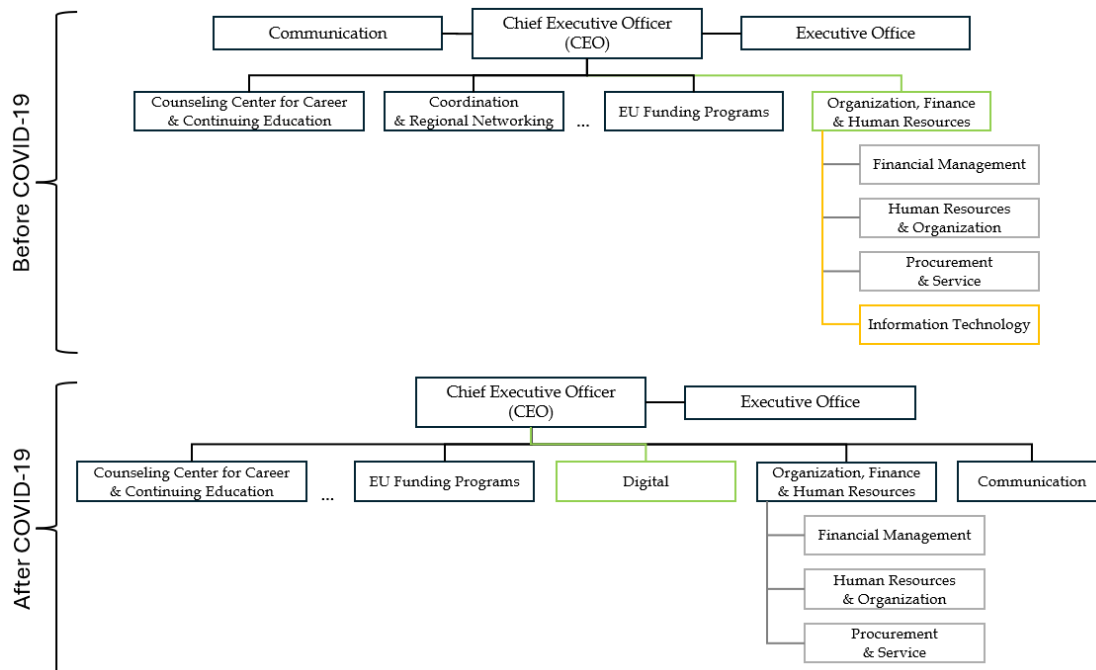
Figure 20: Role of IT/Digital in the Public Organization (Before & After COVID-19)

AI Tools:

The planned implementation of AI tools signifies a broader trend towards IT and process digitization, marking a transition from paper-based methods to solutions that enhance flexibility and location independence. This shift underscores management's recognition of the necessity for modern tools to optimize operational efficiency.

Digitalization:

Most respondents believe that COVID-19 has accelerated digitalization. IT is now more integrated into all processes, with a push for self-service tools and cloud solutions.

Documentation & Know-How-Sharing:

The organization has upgraded its documentation and knowledge-sharing practices. Enhancements to the time recording and office booking systems now feature remote work tracking and managerial approval, helping to standardize and streamline processes.

The development of a structured Wiki has further highlighted the importance of making crucial knowledge widely accessible, underlining the role of effective knowledge sharing in organizational success.

The pandemic has shifted the emphasis to more comprehensive software documentation. The move to email-based requests and mandatory team leader

approval has streamlined workflows, but there is now a greater need for on-site support and detailed documentation to preserve internal expertise and address increased demands for assistance.

It has become increasingly important to document existing know-how related to software projects. According to most respondents, the level of documentation has increased, with COVID-19 accelerating this process.

Before the pandemic, there was already a helpdesk in place to address general IT questions and help with issues. The helpdesk created guides and how-tos to facilitate the transition to remote work. These documents have been also maintained and updated since the pandemic.

6.3.5 Recommendations for Software Projects in Public Sector

This chapter offers recommendations for improving software projects in the public sector. Key suggestions include promoting cloud training, enhancing requirement documentation, implementing a unified digital strategy, and standardizing tool usage. These steps address challenges and improve project outcomes in the public sector:

Promote Cloud Training:

Offering comprehensive training sessions is crucial for maximizing the benefits of cloud technologies and ensuring employees are proficient in using these tools effectively. Focusing on practical aspects of cloud tools and services, these sessions will equip employees with the necessary skills and knowledge for optimal performance.

Enhance Requirement Documentation Practices: Standardizing and streamlining the documentation process in Jira is essential for improving clarity and minimizing errors. By implementing best practices for documenting requirements, organizations can ensure that tickets are clear, actionable, and consistently formatted.

Implementation of a Unified Digital Strategy:

To ensure a cohesive and forward-looking approach, it is essential to implement a unified digital strategy. This involves developing and executing a comprehensive plan that not only addresses critical aspects such as data security and IT infrastructure but also aligns with long-term business goals. By integrating these elements into a single strategic framework, organizations can effectively safeguard their digital assets, optimize their technological infrastructure, and drive sustainable growth.

Standardizing Tool Usage:

To address the issue of tools that were not uniformly implemented during the pandemic and are currently being used as duplicates, it is recommended to conduct a thorough audit of all tools in use across the organization. This audit should identify overlapping functionalities and usage patterns.

6.4   Summary

This chapter addresses the methodology used for conducting interviews, analyzing transcripts with MAXQDA Analytics Pro, and evaluating the data related to the enduring effects of COVID-19 on software development projects in the public sector. It emphasizes a systematic and thorough approach to data analysis, grounded in Mayring's framework.

These thematic areas were carefully crafted through a SLR creating an interview guideline. The guideline used in the interviews was designed to uphold objectivity and avoid influencing the responses. It was organized into four main blocks: Project Management, Home Office, Requirements Management, and Corporate Business and Team Management.

In the subsection Discussions, a bridge was established between the pre-, during- and post-COVID-19 periods. This bridging highlighted 10 lasting impacts of COVID-19 on software development projects in the public sector. The figure below outlines the high-level process and results of the semi-structured interviews. It highlights the key steps involved, leading to the identification of 10 lasting impacts. These impacts are clearly shown on the right side of the figure:
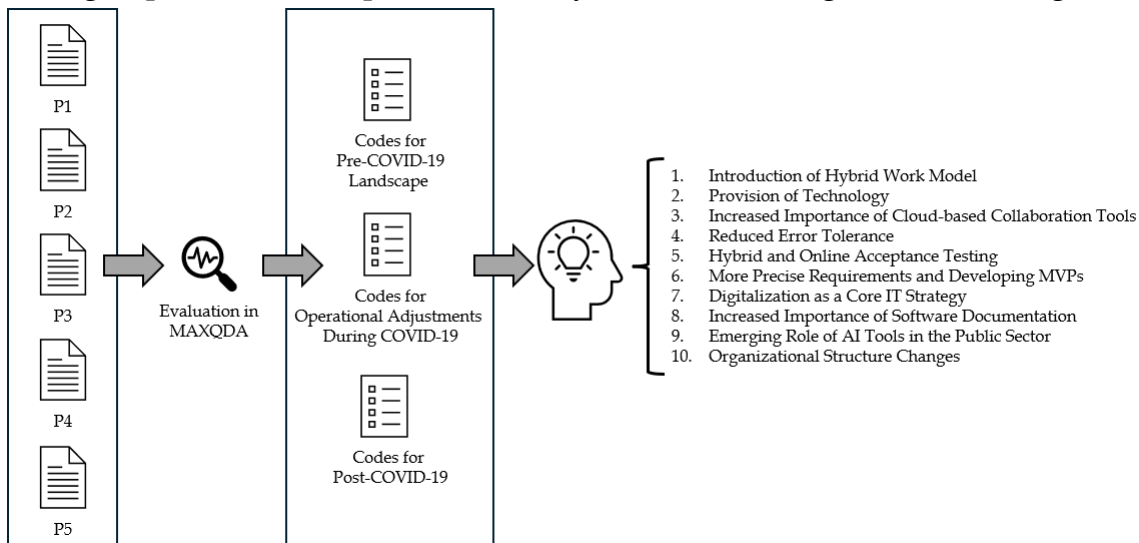
Figure 21: Lasting Impacts of COVID-19 on Software Development Projects in Public Sector

Additionally, it outlined practical recommendations based on the findings, providing actionable insights for improving software development practices in the context of ongoing or future challenges. Specifically, the recommendations included promoting cloud training to enhance adaptability, improving requirement documentation practices for better project clarity, implementing a unified digital strategy to streamline operations, and standardizing tool usage to ensure consistency and efficiency across projects.

7   Discussion & Interpretation

In this final chapter, the findings are interpreted, with a focus on the RQ1 of identifying the lasting impacts of COVID-19 on software development projects in the public sector. Detailed answers to the sub-research questions RQ1.1, RQ1.2, and RQ1.3 are also provided, summarizing the outcome of the study.

7.1   Addressing RQ 1

The COVID-19 pandemic has shed several lasting impacts to software development projects within the public sector:

- Introduction of Hybrid Work Model
- Provision of Technology
- Increased Importance of Cloud-based Collaboration Tools
- Reduced Error Tolerance
- Hybrid and Online Acceptance Testing
- More Precise Requirements and Developing MVPs
- Digitalization as a Core IT Strategy
- Increased Importance of Software Documentation
- Emerging Role of AI Tools in the Public Sector
- Organizational Structure Changes

In the following subsections, the sub-research questions RQ1.1, RQ1.2, and RQ1.3 are answered.

7.1.1   Addressing RQ 1.1

This subsection examines the initial situation of software projects before the COVID-19 pandemic.

Before the COVID-19 pandemic, the initial situation of software projects was characterized by a strict office-only work environment. Employees were required to work exclusively from the office, either in their own private offices or sharing a space with one or two colleagues. There was no option for home office. Meetings, including those with software vendors, were always conducted in the office, and organizing video conferences was not allowed.

Requirements for projects were documented only at a high level. Tools like Jira, and sometimes MS Word were used for this purpose. There was no formal review process for these requirements before implementation began. Requirements were estimated in terms of Story Points.

The development process followed a six-week cycle. Concurrently, a six-week analysis phase for the upcoming version was conducted. At the end of each six-week cycle, a new version of the software would go live.

Software projects had little to no documentation to facilitate knowledge transfer. Employees did not receive smartphones or laptops; everyone used desktop PCs in the office. Terminal servers were the standard, and cloud tools were used minimally, primarily for experimental purposes.

Lastly, the IT strategy was not clearly communicated in the IT department.

7.1.2 Addressing RQ 1.2

This subsection focuses on how the pandemic has impacted pandemic impacted the software projects in public sector.

With the onset of the lockdown, project work rapidly transitioned to a home office setup. Initially, this was challenging due to hardware shortages. However, every employee was eventually equipped with a smartphone and a notebook for home office work, and policies were adjusted to allow the use of personal devices for work purposes.

Meetings were shifted to an online format, with all meetings being organized via video conference. This included meetings with software vendors, which were also conducted through video conferencing. Cloud-based collaboration tools were utilized during these meetings, and a cloud storage solution was suddenly introduced.

There was a sudden influx of requirements, both internally and from other public organizations. Jira, a project management tool, gained greater significance and became the single point of truth. A review process for requirements was introduced.

The length of development cycles remained unchanged, but the content and priorities shifted rapidly. There was a notable increase in requirements related to digitalization and automation, with digitalization receiving higher priority.

During the pandemic, the organization adopted a more agile approach. Due to the speed of implementation required, it was no longer feasible to execute large requirements all at once. Instead, requirements were broken down into smaller parts and implemented over multiple cycles, ensuring that systems continuously received the most prioritized features. This approach focused on delivering Minimum Viable Products (MVPs), allowing the organization to quickly adapt and address the most critical needs first.

Despite frequent priority changes, the tolerance for errors increased during these stressful times.

Furthermore, the creation of software documentation became more important.

7.1.3 Addressing RQ 1.3

This subsection interprets the effects that are still present today in software development projects since the end of the pandemic.

Introduction of Hybrid Work Model:

A hybrid work model has been introduced where employees work two days in the office and three days from home. Those working in the office must reserve a workspace through a booking system.

Provision of Technology:

To facilitate continued remote work, all employees have been provided with smartphones and laptops, ensuring they can work efficiently from any location.

Increased Importance of Cloud Tools:

Cloud-based collaboration tools have gained significant importance in software projects. A new policy mandates that data must be stored in cloud storage rather than on terminal servers as was common during and before the pandemic.

Reduced Error Tolerance:

Post-pandemic, there is no longer the same level of error tolerance that existed during the pandemic. The standards and expectations have reverted to higher pre-pandemic levels.

Hybrid and Online Acceptance Testing:

Acceptance tests are now conducted in a hybrid manner or online via screen sharing. However, this method poses more challenges for older employees.

More Precise Requirements and Developing MVPs:

The requirements for software projects are now more precisely defined. The importance of documenting decisions and requirements in Jira has been recognized and consistently implemented. Additionally, the concept of MVP (Minimum Viable Product) is now an integral part of the requirements engineering.

Digitalization as a Core IT Strategy:

Digitalization has become a core component of the IT strategy. It is widely acknowledged that the IT strategy must be an integral part of the overall business strategy.

Increased Importance of Software Documentation:

Software documentation has become more crucial. In public sector software projects, where older employees with significant know-how are predominant, it has been identified that this knowledge must be preserved to ensure project continuity during absences.

Organizational Structure Changes:

The organizational structure has evolved, allowing the Head of IT/Digital to be in direct contact with the CEO from the start, ensuring their involvement in decision-making processes.

8 Conclusions and Future Work

The COVID-19 pandemic drastically altered life across the globe, leading to widespread illness and potentially long-term impacts on human organizations. This period also supposed significant impacts for software development projects in public sector. To explore these impacts in detail, this master's thesis employed a (SLR) methodology, as outlined by Kitchenham and Charters (2007).

The study began by developing a search string focused on the "impacts of COVID-19 in software development projects." The identified papers were systematically reviewed, and data from these papers were extracted into a structured template. The results of the SLR provided a mapping of impacts, challenges, and recommendations, categorized into three distinct time periods: before-, during-, and after COVID-19. Based on the identified impacts from the SLR, an interview guideline for semi-structured interviews was developed.

Interviews were conducted with five experts from software development projects within the public sector. The interviews were transcribed in German using, manually reviewed for accuracy, and subsequently translated into English. In conclusion, the predetermined thematic areas from the guidelines were discussed in the context of the periods before-, during-, and after COVID-19.

The findings were presented in relation to the research questions, revealing the lasting impacts of COVID-19 on software development projects within the public sector. These insights underscore the significant and enduring changes brought about by the pandemic in this field.

The lasting impacts of COVID-19 on software development projects in the public sector include the introduction of hybrid work models, enhanced provision of technology, a greater emphasis on cloud-based collaboration tools, reduced error tolerance, hybrid and online acceptance testing, more precise requirements and developing MVPs, the digitalization of core IT strategies, changes in organizational structures, increased importance of software documentation, and the emerging role of AI tools.

Extending the study to encompass industries, like businesses, healthcare or education could give a broader perspective on the effects of COVID-19 on software development in different fields. This comparative method could reveal challenges and adjustments specific, to each sector.

Potential future research could be directed toward the identification of the patterns and creation of the guidelines and policies for best practice models based on the results of the present research. This would assist organizations within the public sector and others to establish and/or fine-tune strategies that could be used to manage software development projects especially within the lens of the existing and emerging disruptions.

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Appendix

GitHub Repository Link:

File Name	Description
Papers evaluated.zip	The zip file "SLR_2_Analysis.zip" contains three sub-directories that organize the papers analyzed during the systematic literature review (SLR). These sub-directories categorize the papers based on their relevance and usage in the SLR, providing a structured approach to the literature review process. **Sub-Directories:** **Text_not_relevant:** This sub-directory contains 1 paper that were marked as not relevant during the text review phase. **Papers_cited:** This sub-directory includes 22 papers that were cited in the systematic literature review. These papers are considered highly relevant and significant to the research questions and topics addressed in the SLR. Each paper in this directory has been referenced in the analysis and synthesis of the literature. **International_Conferences:** This sub-directory contains 2 papers from international conferences. Among these, three specific papers were cited in the master's thesis and have been individually saved by title in the "Papers_cited" sub-directory
SLR_1_ListofAllPapers.xlsx	This file is a comprehensive spreadsheet that lists all the academic papers identified through a systematic literature review (SLR). The papers included in this file were selected based on a predefined search command and specific filter criteria. This document serves as an essential input for conducting the SLR, providing a detailed overview of the relevant literature in the field.
SLR_2_Analysis.xlsx	The file is a detailed spreadsheet that contains the analysis of academic papers selected for the systematic literature review (SLR). This file includes papers that have been thoroughly screened to remove duplicates and analyzed following the methodology described in Chapter 4.3 of the Systematic Literature Review guidelines.
SLR_3_Summary.xlsx	This file contains summaries for impacts, challenges and recommendations.

Table 33: Appendix 1

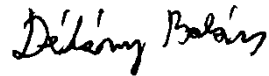| File Name	Description
Transcripts.zip	Transcripts of semi-structured interviews in original language, German, and translated to English.
MA_project_in_MAXQDA.mx24	This is the MAXQDA-project for analysis and evaluation of interview transcripts.
Experts_Statistic.xlsx	This file provides anonymized overview about experts, involved in interviews.

Table 34: Appendix 2

Declaration of Academic Honesty

I hereby declare on my word of honor, that I created the thesis at hand independently, that I did not use any material other than the cited resources and that I have marked all results created by somebody else, be they quoted in my thesis word for word or by a matter of meaning, accordingly.

I further declare that the thesis at hand has not been submitted to any other institution (university, university of applied sciences, university of education or other comparable institution) to obtain any academic degree.

Eisenstadt, 13.08.2024

Location, date

Signature