BUSTECH 2025

The Fifteenth International Conference on Business Intelligence and Technology

ISBN: 978-1-68558-265-4

April 6 - 10, 2025

Valencia, Spain

BUSTECH 2025 Editors

Pierre Hadaya, University of Quebec in Montreal, Canada

BUSTECH 2025

Forward

The Fifteenth International Conference on Business Intelligence and Technology (BUSTECH 2025), held on April 6 – 10, 2025, continued a series of events covering topics related to business process management and intelligence, integration and interoperability of different approaches, technology-oriented business solutions and specific features to be considered in business/technology development.

Similar to the previous edition, this event attracted excellent contributions and active participation from all over the world. We were very pleased to receive top quality contributions.

We take here the opportunity to warmly thank all the members of the BUSTECH 2025 technical program committee, as well as the numerous reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and effort to contribute to BUSTECH 2025. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations and sponsors. We also gratefully thank the members of the BUSTECH 2025 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope BUSTECH 2025 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of business intelligence and technology. We also hope that Valencia provided a pleasant environment during the conference and everyone saved some time to enjoy this beautiful city.

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How Does AI Influence the Acceptance of Business Intelligence Solutions in Switzerland?

A Case Study of Swiss BI Software Company

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Abstract— **This study explores how Artificial Intelligence (AI) influences the acceptance and adoption of Business Intelligence (BI) solutions in Swiss companies. With AI rapidly reshaping industries and boosting productivity, the research investigates how AI enhances BI systems in decision-making, operational efficiency, and data-driven strategies. A qualitative case study was conducted through an anonymized interview with the director of a Swiss software company specializing in BI solutions. The research identifies key challenges in BI adoption, such as data integration, financial constraints, and the need for internal expertise, while examining how AI addresses these barriers. It also explores whether AI complements or competes with traditional BI tools, revealing that AI enhances BI by automating tasks, improving data accessibility, and enabling real-time insights. The findings contribute to theoretical frameworks like the technological, organizational, and environmental (TOE) framework, dynamic capabilities theory, and the resource-based view (RBV), highlighting AI's role in advancing BI systems and organizational agility.**

Keywords—Artificial Intelligence; Business Intelligence; Switzerland; BI Adoption.

I. INTRODUCTION

Artificial Intelligence (AI) is rapidly transforming industries worldwide, driving significant economic growth and reshaping business operations. Projections indicate that AI could contribute up to $15.7 trillion to the global economy by 2030 [23]. This underscores AI's pivotal role in enhancing productivity, especially through integration into workflows, which improves efficiency among younger employees [18].

Simultaneously, the global Business Intelligence (BI) software market is projected to reach USD 151.26 billion by 2034, with a compound annual growth rate (CAGR) of 13.74% [22]. BI solutions have become essential tools for data-driven decision-making, operational efficiency, and strategic planning [1]. The core principles of BI revolve around collecting, integrating, analyzing, and presenting business data in ways that support informed managerial decision-making. As AI technologies advance, their integration into BI systems is reshaping the BI landscape by enabling automation, predictive insights, and real-time data accessibility. This technological convergence is likely to accelerate BI adoption across industries.

In Switzerland, AI adoption is progressing steadily. A 2023 survey reports that 62% of professionals have implemented AI, with 30.6% using it across five or more business functions [27]. This reflects Swiss companies' increasing reliance on AI to drive innovation and maintain competitiveness.

Despite growing implementation, the actual impact of AI on productivity remains ambiguous, echoing the historical "Solow paradox" observed with earlier technologies [12], [26]. As a result, a deeper understanding is needed of how AI transforms business processes, particularly in combination with BI tools.

This study aims to examine how AI influences the acceptance and adoption of BI solutions among Swiss companies. Specifically, the purpose of this article is to explore whether AI acts as a complementary technology or a potential competitor to traditional BI systems, and how it transforms decision-making, operational efficiency, and data strategies.

Based on these goals, the study investigates the challenges of BI adoption in Switzerland, the role of BI in enhancing organizational efficiency, and how AI affects BI system capabilities. The specific research questions guiding this study are detailed in Section III.

The remainder of the article is structured as follows: Section II reviews relevant literature and theoretical frameworks on BI and AI adoption. Section III formulates the research questions. Section IV outlines the research methodology and case study design. Section V presents and analyzes the empirical findings. Finally, Section VI discusses the conclusions, theoretical contributions, limitations, and recommendations for future research.

II. RELATED LITERATURE

A. Theoretical framework for adoption of BI solutions

A wide range of theoretical frameworks have been used to understand the adoption and use of Business Intelligence (BI) solutions in organizations. These include socio-technical systems theory (STS), diffusion of innovation (DOI),

institutional theory (IT), unified theory of acceptance and use of technology (UTAUT), business intelligence maturity models (BIMM), and business value of BI (BVBI). While these models offer valuable conceptual insights and have been successfully applied in various technology adoption studies, they are often more general or focus on user acceptance, institutional influence, or long-term maturity progression.

For the purpose of this study, which aims to understand how Swiss companies adopt BI tools and integrate AI into these systems, we focus on three frameworks that are most relevant and directly applicable to the empirical setting: the Technological-Organizational-Environmental (TOE) framework, the Resource-Based View (RBV), and Dynamic Capabilities Theory (DCT) (Table 1).

TABLE I. RESEARCH METHOD FRAMEWORK

Theoretical Framework	Common Focus	Specific Contribution to BI Adoption in Switzerland
TOE	Technology, organization, environment	Captures external pressures and internal readiness; explains how Swiss firms respond to regulations and tech opportunities
RBV	Internal capabilities and resources	Explains disparities in adoption success based on firm-specific assets and competencies
DCT	Adaptation and responsiveness to change	Highlights how firms integrate AI into BI by reconfiguring processes and enhancing agility

The TOE framework [2], [3], [15] offers a comprehensive lens for examining BI adoption by considering technological factors (such as the scalability and accessibility of BI software), organizational factors (including leadership support and internal expertise), and environmental influences (such as regulatory requirements and competitive pressure). This framework aligns well with the Swiss context, where both internal resource constraints and external demands play significant roles in digital transformation processes.

The RBV framework [19], [28] emphasizes that companies derive competitive advantage from internal capabilities, including data infrastructure, skilled personnel, and IT resources. In the context of BI, RBV helps explain why some Swiss firms—especially SMEs—struggle more with adoption due to limited internal capacity [20], [24]. It also highlights the importance of aligning BI tools with existing resources to ensure successful implementation.

The DCT framework [2], [7], [10] extends RBV by focusing on how firms adapt, integrate, and reconfigure resources to respond to rapidly changing environments. This is particularly relevant to AI-enhanced BI systems, which require continuous learning, data-driven responsiveness, and organizational agility. DCT provides a useful framework for analyzing how Swiss companies attempt to remain competitive by integrating new technologies like AI into their BI systems.

B. Impact of AI on BI Adoption

The integration of AI within Business Intelligence (BI) systems is reshaping the BI landscape, providing more advanced capabilities and accessibility. A key trend in this transformation is the shift from traditional BI tools to AI-powered systems capable of processing vast datasets in real-time and providing actionable insights. AI technologies, such as machine learning and natural language processing (NLP), enable BI systems to automatically detect patterns, generate predictive models, and offer insights without requiring extensive manual intervention. This change is especially significant in industries where fast decision-making is critical [28].

Another significant trend is the automation of data processing tasks, which increases efficiency and reduces human error. Bharadiya [5]. [6] compares BI and AI, emphasizing how AI enhances BI by automating complex processes like data cleaning, pattern recognition, and trend forecasting. This automation makes BI tools more efficient and accessible, particularly for businesses with limited technical expertise. AI-driven systems allow organizations to leverage BI capabilities without requiring specialized data science knowledge, broadening the accessibility of advanced analytics.

AI also facilitates smarter data management and analytics, improving decision-making processes and boosting organizational agility. Eboigbe [9] argue that AI's integration into BI systems allows businesses to quickly adapt to changing market conditions by generating predictive insights and identifying emerging trends. By automating the data analysis process, AI frees up resources for higher-level strategic tasks, increasing the overall efficiency of the organization. This transformation supports the growing need for real-time insights and agility, particularly in competitive markets

III. RESEARCH QUESTIONS

Despite ample research on BI solutions, the dynamic between AI and BI remains underexplored. Most studies view AI as a complement to BI, enhancing it through automation and predictive analytics [28], [5], [6]. Yet, the possibility of AI competing with or even replacing BI systems is less examined. This study aims to explore how AI might reshape or replace BI, particularly in Switzerland where AI adoption is progressing quickly.

Additionally, although many studies have examined BI adoption in various regions, there is limited research on the specific characteristics of Swiss companies as BI solution customers. Most studies on Swiss BI adoption cover general trends rather than the distinct challenges and opportunities within this market. Gaining insight into these regional nuances is essential for understanding how Swiss companies use BI tools, the business issues they address with BI, and the potential role of AI as a competing or complementary technology. This lack of detailed understanding highlights an opportunity to explore BI tool adoption in Switzerland and assess if AI could provide a better alternative.

This study aims to examine AI's role in influencing the acceptance and adoption of BI solutions among Swiss companies, exploring how AI is transforming the BI landscape as both a complementary technology and a potential competitor or replacement for traditional systems. The study will examine the challenges faced by Swiss market players in adopting BI tools, the business problems these organizations hope to solve with BI, and how AI's capabilities influence the adoption, functionality, and perceived value of BI solutions.

Given the identified research gaps and the goal of the study, the following research questions are formulated:

- ***RQ1:*** *What are the key challenges and factors influencing the adoption of BI solutions across different company sizes in Switzerland?*
- ***RQ2:*** *How do BI solutions enhance decision-making, operational efficiency, and data-driven strategies in organizations?*
- ***RQ3:*** *What is the role of AI in advancing the capabilities and accessibility of BI software for businesses?*

IV. METHODOLOGY

This study uses a qualitative case study approach to explore the adoption and impact of BI solutions, with a particular focus on the role of AI in enhancing BI software (Table 2). The research is based on an anonymized interview with the director of a Swiss BI software company specializing in enterprise resource planning (ERP) systems and BI solutions. This company primarily serves Small and Medium-sized Enterprises (SMEs) across various industries, providing a practical perspective on the challenges and benefits associated with BI adoption.

TABLE II. RESEARCH METHOD FRAMEWORK

Research Questions	**RQ1**	**RQ2**	**RQ3**
Theoretical framework	TOE Framework	Dynamic Capabilities Theory, RBV	AI-BI Relationship
Case study: Corresponding Interview Questions	• What are the main challenges your clients face when adopting BI solutions? • How does company size affect the adoption of BI solutions?	• How do BI tools influence decision-making and operational efficiency? • In what ways do BI tools support data-driven strategies? • What are the limitations of BI tools?	• How does AI improve BI software capabilities? • How will the integration of AI shape the future development of BI software? Do AI and BI complement or compete?

The interview questions were developed to align closely with the research objectives and theoretical frameworks guiding the study. Each question was designed based on the principles of relevance, clarity, and open-endedness, ensuring the collection of rich, qualitative insights. The formulation was guided by the TOE, RBV and DCT frameworks, ensuring that responses would reflect not only technical factors but also organizational resources and strategic adaptability. Furthermore, the questions aimed to elicit specific experiences and perceptions related to the three core research questions (RQ1–RQ3), focusing on adoption challenges, the added value of BI in decision-making, and the transformative role of AI.

The primary data for this research was gathered through a semi-structured interview, allowing the respondent to elaborate on their experiences and provide real-world examples. The conversation focused on the company's experiences with BI implementation, the factors influencing adoption across different contexts, the role of BI in improving decision-making and operational efficiency, and the integration of AI technologies to enhance the accessibility and functionality of BI software. The anonymized nature of the interview ensures confidentiality while retaining the depth of qualitative insights.

A thematic analysis of the interview transcript was conducted to identify key patterns and themes related to BI adoption and usage. Particular attention was paid to challenges such as data integration, resource constraints, and organizational readiness, as well as the role of AI in enabling advanced analytics, automation, and real-time insights. The analysis also examined how BI solutions enhance decision-making and streamline processes for Swiss companies.

While the findings of this study are based on a single case study, they offer valuable insights into the nuanced challenges and opportunities of BI and AI adoption in a real-world context. Ethical considerations were carefully addressed, with the participant's anonymity maintained and the interview conducted in compliance with research ethics guidelines.

V. RESULTS

The results of the qualitative case study highlight several key themes regarding the adoption of BI solutions and the role of AI in enhancing this software within the context of a Swiss BI software company. These findings provide insights into the challenges faced by businesses in adopting BI systems, how BI software enhance organizational capabilities, and the transformative potential of AI within BI technologies.

A. Key challenges and factors influencing BI adoption

The adoption of BI solutions among Swiss companies, both SMEs and larger organizations, is shaped by several key challenges and factors.

One of the primary challenges is data complexity and integration. Many companies operate with separate databases or legacy systems, such as Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM) systems, which store crucial business data. The difficulty lies in consolidating these diverse data sources into a unified platform for efficient analysis: "The problem arises when you have multiple tools with separate datasets. You then have to integrate them, which involves a lot of work." This challenge is particularly pronounced in SMEs that lack the resources and technical expertise to manage complex data

integration tasks, although larger organizations face scalability issues as the volume of data grows.

Financial constraints also present a significant barrier, particularly for smaller companies. The adoption of BI tools involves substantial upfront investment in software, infrastructure, and training: "The entry price is quite expensive... it's a significant barrier for companies with fewer than 150 employees." For SMEs, these high initial costs are often prohibitive, despite the long-term benefits BI can offer in terms of operational efficiency and decision-making. Larger companies are generally better equipped but still need to justify these investments amidst competitive pressures.

Internal expertise and training are another critical factor influencing BI adoption. Many SMEs, in particular, lack the internal expertise to effectively use BI solutions. Even when the technical capabilities of BI tools are available, their success depends on employees' ability to understand and interact with data: "The real need is training on the importance of data—what data is, how it's collected... how it interacts across systems." Proper training is essential for maximizing the value derived from BI systems, but it is often inadequately funded or outsourced, limiting the effective use of the tools.

With the growing integration of AI into BI tools, the question of whether Swiss companies are skill-wise prepared to handle AI-enhanced BI becomes increasingly relevant. According to the interview findings, the general level of preparedness—especially among SMEs—is relatively limited. Although some firms demonstrate awareness and interest in AI capabilities, there remains a significant gap between interest and actual readiness to implement AI within BI systems.

Scalability is a concern for larger organizations that require BI tools capable of handling larger datasets and more complex analytics needs. The representative mentioned, "Larger companies often have a lot of detailed requirements and processes to manage," adding to the complexity of BI adoption. While scalability is essential for large organizations, even SMEs need tools that can evolve with their growing data and increasingly data-driven decision-making processes.

Another challenge is the availability and accessibility of clean, well-organized data. Many companies, especially SMEs, struggle to centralize or standardize their data. Without a clear strategy for data management and governance, businesses find it difficult to make full use of BI solutions: "It's critically important to rationalize and centralize these data sources." Companies lacking centralized, structured data cannot easily leverage BI tools, which limits their ability to generate valuable insights.

Lastly, the usability of BI tools is a significant factor for adoption across organizations. For BI tools to be effective, they must be user-friendly, enabling employees to easily interact with data to make informed decisions: "Tools like Tableau or Power BI are very intuitive... can easily ask something like, 'Can you show me my top-performing sales lines over the past year?'" These user-friendly interfaces encourage adoption, especially among non-technical employees who may not have experience with complex data analysis.

In industries like manufacturing, where data generation is high due to connected machinery, the need for advanced BI tools is especially evident. The representative noted, "If you are a manufacturing company, of course, you generate much more data because you likely have machines producing data." Industry-specific factors, such as the volume of data generated, play a critical role in driving the need for robust BI systems to manage and analyse the data effectively.

In summary, while all the above challenges play a role in shaping BI adoption, internal expertise gaps, financial barriers, and data integration issues were most frequently emphasized in the interview. Other concerns, such as scalability, data quality, and usability, were mentioned less often but still represent meaningful considerations depending on company size and context.

B. Enhancing decision-making and operational efficiency

BI solutions have significantly contributed to enhancing decision-making and operational efficiency in Swiss companies. One of the primary ways BI solutions impact decision-making is by enabling real-time data access: "With BI, we can see data in real-time, which allows management to make decisions faster and based on accurate data". This immediacy in data access empowers organizations to act swiftly, reducing reliance on outdated information and enabling more informed and timely decisions.

The ability to generate clear and actionable insights is another benefit of BI systems: "BI tools provide clear and actionable dashboards, allowing managers to track their budget performance and align with targets in real-time". This real-time monitoring not only aids decision-makers in aligning their operations with business goals but also ensures that key performance indicators (KPIs) are continuously evaluated, which helps organizations stay on course.

Furthermore, the integration of BI tools within organizations promotes better resource allocation and improves efficiency across departments: "BI systems help us allocate resources more effectively by identifying areas where we are underperforming or could improve". By pinpointing inefficiencies or gaps in performance, companies can reallocate resources to optimize operations, improving both productivity and profitability.

A significant advantage of BI solutions is their ability to automate manual processes, thus reducing time and effort in data management: "Previously, departments like finance had to compile reports manually and share them across the organization. Now with BI, that process is streamlined and automated". This reduction in manual work enhances operational efficiency, enabling employees to focus on higher-value tasks that drive business growth.

BI solutions also facilitate strategic alignment across departments. With a single, unified data source, "everyone has access to real-time information, enabling seamless collaboration and more informed decisions". This transparency across teams ensures that all stakeholders are working toward the same business objectives, fostering alignment and reducing discrepancies in decision-making.

Despite these advantages, the interview also shed light on the limitations of BI solutions. While BI tools provide vast benefits, there are areas where they still fall short. For instance, while BI systems can predict trends and offer insights, the representative mentioned that “many companies don’t have sufficient time-series data to build accurate forecasts”. This suggests that the effectiveness of BI tools in predictive analytics is contingent upon the quality and scope of the available data, which may limit their utility in some cases.

C. The role of AI in advancing BI capabilities

The integration of AI into BI software is revolutionizing how organizations manage, analyse, and utilize data. As AI continues to evolve, its impact on BI tools has expanded significantly, enhancing their capabilities and accessibility. According to the director of a Swiss BI software company, AI-driven BI systems are able to automate complex tasks such as data cleaning and trend forecasting, which traditionally consumed a significant amount of time and resources: "AI has made BI more efficient by automating complex tasks like data cleaning and trend forecasting. This saves a lot of time and effort". This automation not only improves the operational efficiency of organizations but also frees up resources that can be used for more strategic activities, enhancing overall business productivity.

One of the most notable advancements is in the area of data accessibility and user interaction. AI’s ability to enable natural language processing (NLP) allows users to interact with BI systems using conversational commands, which significantly lowers the barrier for non-technical users. The interview highlighted this development: "With AI-driven BI systems, users can interact with the system using natural language. For example, you can simply ask the system, ‘Show me my top-performing sales lines,’ and AI will generate the necessary data visualizations". This shift democratizes access to data, empowering individuals across an organization to derive actionable insights without requiring specialized technical knowledge.

AI also plays a critical role in predictive analytics, enabling BI systems to deliver real-time insights and trend forecasts: "AI enables more accurate predictions by analysing historical data and identifying patterns. This allows businesses to forecast trends and make proactive decisions". By leveraging AI's capabilities, companies can adjust strategies faster and stay competitive in a rapidly changing environment. The real-time nature of these insights enhances decision-making, allowing managers to act quickly and efficiently.

Further, AI-driven BI systems streamline data analysis by improving decision-making speed: "AI speeds up decision-making by providing insights in real-time. When data is processed automatically, managers can get information much faster, allowing them to make informed decisions quickly". This ability to process and analyse data instantaneously supports quicker, data-driven decision-making across various business functions, including sales, marketing, and operations.

While the role of AI in enhancing BI systems is increasingly significant, it raises the question of how the development of BI software will evolve with the continued integration of AI. The interview suggested that, in the future, AI will become an integral part of BI systems, with a growing shift towards fully automated and integrated solutions: "AI is integrated with existing systems like ERP platforms, making BI a more seamless part of daily business operations. It simplifies workflows by bringing all data together in one place for easier access and analysis". As AI continues to advance, BI systems will likely evolve into even more powerful tools capable of handling larger volumes of data and providing even more sophisticated insights. The future of BI software lies in fully automated systems where "all data flows into a centralized data lake and insights are generated dynamically".

When considering whether AI and BI complement each other or compete, the interview made it clear that AI is not competing with BI but instead enhancing its capabilities. "AI doesn’t replace BI; it complements it by automating tasks and making it more accessible,". The integration of AI into BI systems enhances their utility by providing additional functionalities that were previously difficult or impossible to achieve, such as predictive analytics, real-time insights, and improved data accuracy. Thus, AI and BI work together to create more efficient, intelligent, and accessible systems that enable businesses to make data-driven decisions faster and more accurately.

VI. CONCLUSION

This study explored how Artificial Intelligence (AI) influences the acceptance and adoption of Business Intelligence (BI) solutions in Switzerland, with a focus on understanding whether AI serves as a complement or a potential alternative to traditional BI systems. The findings, based on a qualitative case study of a Swiss BI software company, provide important insights for both practice and theory.

In response to the first research question (RQ1), the study found that the most frequently mentioned challenges affecting BI adoption in Switzerland include lack of internal expertise, financial constraints—especially for SMEs—and technical barriers related to data integration. Less commonly but still notably, issues of data centralization, tool scalability, and usability also shape adoption outcomes.

Regarding the second research question (RQ2), BI solutions were described as significantly enhancing decision-making and operational efficiency through real-time access to data, improved resource allocation, and better alignment with performance targets. However, the effectiveness of BI in predictive analytics is still limited by the quality and scope of available data.

For the third research question (RQ3), the integration of AI into BI systems was found to enhance functionality by automating complex tasks, enabling natural language queries, and improving accessibility for non-technical users. AI was not perceived as competing with BI, but rather as extending its capabilities, especially in areas like predictive analytics and real-time insights.

From a theoretical perspective, the study contributes to the TOE framework by highlighting how AI integration influences both the technological and organizational dimensions of BI adoption, particularly in resource-constrained environments like Swiss SMEs. It also reinforces the Dynamic Capabilities Theory by demonstrating how AI-powered BI systems support firms' ability to sense and respond to market dynamics. Finally, the findings support the RBV by showing that firms with stronger internal resources—especially data-literate employees—are better positioned to capture value from AI-enhanced BI tools.

The Swiss context reveals a practical gap between the increasing technological potential of BI-AI systems and companies' internal readiness to adopt them effectively. Based on the empirical insights, companies in Switzerland—particularly SMEs—would benefit from focusing their efforts on upskilling staff in both BI and AI simultaneously, prioritizing structured data management, and starting with modest, application-specific use cases that align with their strategic needs. Larger firms, meanwhile, should focus on integrating AI capabilities directly into their existing BI infrastructures and workflows to scale benefits more rapidly. These actions, grounded in observed Swiss practice, could help companies realize the full potential of AI-enhanced BI tools.

Although this study focuses on a single case in Switzerland, the findings are relevant for other national contexts where SMEs dominate and digital transformation is progressing. The lessons derived from the Swiss experience—particularly the importance of understanding BI and AI as interconnected rather than separate tools—can inform global strategies for intelligent data use in business environments increasingly shaped by automation and analytics.

Future research should expand on these insights by including multiple cases across sectors and countries to better capture the diversity of organizational strategies for AI-BI integration and to explore long-term performance outcomes.

ACKNOWLEDGMENT

This research was conducted as part of the BISWISS project, supported by the School of Management Fribourg (HES-SO). I would like to extend my sincere thanks to the director of the Swiss BI software company, whose insights and experiences greatly contributed to the development of this study. Their input was invaluable in shaping the findings presented in this paper.

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Critical Success Factors for Application of Business Intelligence in Distribution Sector in Denmark

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***Abstract*— This working paper explores the Critical Success Factors for application of Business Intelligence (BI) tools in the distribution sector, focusing on their impact on overall decision-making and strategic planning, data quality, and organizational culture. Through interviews with two distribution companies, the research confirms existing discussions regarding the success factors in implementation of BI technologies and its perceived benefits. Key themes emerged, including the enhancement of data-driven decision-making processes and strategic planning, the importance of data quality for effective BI utilization, and the cultural shifts towards a more analytical approach within organizations. The findings highlight that while the interviews reaffirm established knowledge on impact of applying BI in business, they also emphasis a holistic approach towards organizational development in optimizing operational efficiency and fostering a competitive edge in the distribution industry. This paper aims to contribute to the understanding of how BI can be leveraged to drive performance and adapt to evolving market demands.**

Keywords- Business Intelligence application; Business Intelligence in distribution sector; Data driven approach with BI

I. INTRODUCTION

In an increasingly competitive global marketplace, the distribution sector faces mounting pressures to enhance efficiency, reduce costs, and improve customer satisfaction. Business Intelligence (BI) tools have emerged as pivotal assets in this landscape, enabling organizations to transform vast amounts of data into actionable insights. Meanwhile, studies suggest Critical Success Factors (CSFs), such as management support, data capability, user involvement, competence development among others to be essential for BI success [1][2].

However, BI implementation is complicated and costly as it requires software, infrastructure, licenses, training and wages [1]. Similarly, in comparison to large enterprises, small & medium enterprises (SMEs) lack the main assets, such as the ability to build extensive sales network and the ease to obtain capital or a recognizable brand [3]. So, they might be reluctant or face challenges to integrate BI successfully.

On the other hand, SMEs in Denmark are considered to highly digitally mature as a study of level of digital maturity amongst EU countries showed that the most digitally developed SMEs were found in Denmark and Finland [4]. It is thus interesting to explore how the SMEs in Denmark have succeeded with digital transformation for instance with BI application and which factors have been critical.

Additionally, BI has been increasingly recognized as a key enabler of Supply Chain Agility, which allows businesses to respond dynamically to unpredictable market conditions [5]. Traditional supply chains often struggle with inefficiencies, rigid structures, and slow adaptability. By integrating BI tools in supply chain management (SCM), organizations can enhance real-time decision-making, demand forecasting, supplier management, and logistics efficiency**.** The ability to plan, source, make, deliver, and return goods efficiently is crucial for distribution companies, and BI provides insights that reduce uncertainty and optimize these processes [5]. In particular, BI supports SCM by improving flexibility, responsiveness, quickness, and competency**,** all of which are core characteristics of an agile supply chain. Given the importance of supply chain agility in today's volatile business environment, understanding how Danish SMEs leverage BI to achieve SCM efficiency can provide valuable insights into digital transformation best practices. Hence, this working paper explores the CSFs in integration of BI tools within the distribution sector in Denmark.

By analyzing case studies and interviews, we aim to highlight how BI application not only streamline operations but also foster a data-driven culture that empowers organizations to adapt swiftly to market changes. However, our goal is not to find generalizable, "One size fit all" manuals but rather provide a nuanced understanding of factors that can lead to BI tools success in shaping the future of distribution, offering valuable insights for practitioners and researchers alike by exploring the CSFs.

The next section presents the main research topic BI and the CSFs through related work with purpose to establish the context of the research. Section 3 presents the research design, followed by data analysis and finding in Section 4. Discussion is presented in Section 5 and conclusion is presented in the final section together with future perspectives.

II. RELATED WORK

BI implementations within an organization comprise many information systems that work together in an

integrated fashion to provide the user with the needed decision support [6]. It is an analytical, technology supported process which gathers and transforms fragmented data of enterprises and markets into information or knowledge about objectives, opportunities and positions of an organization [7]. Considering the large diversity of application areas as BI and corresponding software products, BI tools vary widely in terms of functionality, sophistication and complexity [7].

Although many organizations view BI as a purely technological investment, several internal and external factors affect its business value [1]. In this connection, several studies have discussed the critical success factors that are essential for a successful implementation of BI systems [3][6]-[9]. Understanding CSFs enables the BI users to optimize their scarce resources and effort by focusing on those significant factors that are most likely to aid successful system implementation [8] and to identify and prioritize both business needs and technical systems [1].

These researches focus largely on two different perspectives – technical/technology and business management [1][2][3][8]. Data capacity, user involvement, organization and competence development, strategy & decision making are some of the re-occurring themes in these studies, followed by several sub-areas such as information quality, data accessibility, system quality, user satisfaction, IT infrastructure, vision & strategy, organization culture, leadership, organization development, attitude towards change among others.

Deriving from these studies, the following four thematic areas were narrowed down for exploring the CSFs in this paper; Data accessibility & quality, Decision making processes and strategic planning, Benefits and impact of BI application on organization and Organization culture & practice.

III. RESEARCH DESIGN

This working paper employs a qualitative case study approach to explore CSFs for BI application within the distribution sector. The study method is selected for its ability to provide in-depth insights into complex phenomena within real-life context. The main objective of this paper is to explore the critical success factors for integrating BI within the distribution sector in Denmark.

Although the nature of this research is explorative, the related work provided the basis for developing an interview guide by identifying the thematic areas as a departure point. Data was collected through semi-structured interviews with key personnel from each company. The interviews varied from 30 minutes to approximately an hour, as the semi - structured interview provided the flexibility to have a conversation with the interviewee without rigid question-answer format. Not all questions were presented but the interview guide was used as a checklist during the interviews.

A. *Case study companies*

Two SMEs within the distribution sector, Danske Værktøjs Agentur (DVA) and Erik Larsen & Søn (ELS) with 36 and 12 employees respectively, were selected as case studies, based on their active use of BI tools and their willingness to participate in the research. Both companies supply tools and materials to B2B clients in construction industry mostly in Denmark and Scandinavia. DVA uses Power BI while ELS uses Qlik as BI tools.

We interviewed Jan Nielsen, Business and Data analytics Manager from DVA and Peter Brinkmann, CEO from ELS. Both interviewees have worked with their respective companies for more than 6 years. Both companies have a steady growth in the recent years and have been applying BI approximately for 5-6 years.

Figure 1. Case companies' Gross profit from 2020-2024
Source – www.proff.dk

IV. DATA ANALYSIS AND FINDINGS

Our data analysis provided a strong confirmation of established concepts regarding the application of BI and CSFs in business contexts. Here we present our findings using thematic areas identified through the literature review.

A. *Data accessibility and quality*

Both companies have had a tradition of systematic data approach even prior to the BI implementation although their approach to decision making has strengthened with the insights from BI. The interviewees acknowledged that the effectiveness of BI tools is contingent upon the integrity of the data being analyzed.

ELS have regular dialogue with the system developers to ensure smooth transaction and to solve problems and challenges and believe that easy access to both data and technology (technical help) to be essential for BI success.

Even though DVA seems to be impulsive when looking at their records of acquisition, Jan stresses on the fact that they ensure the compatibility of the outcoming data and do spend necessary resources before integrating to the existing database. Furthermore, they have a good relationship and cooperation with the BI system developers, so they can easily adjust their database and analysis tools whenever necessary with regular feedback and problem-solving mindset.

B. Decision Making and Strategic planning

Both companies emphasized the role of BI tools in enhancing decision-making processes. The ability to analyze real-time data allowed for more informed choices, reducing reliance on intuition alone.

The interviews revealed that BI tools are integral to strategic planning efforts. For instance, DVA plans its orders and deliveries through the system that monitors the current inventory and the flow/trends in the market, so that they do not run out of the supplies as well as the supplies do not take spaces for longer time than necessary. This releases time and resources for the managers while increasing operational efficiency.

At ELS, 4 managers have access to BI where they get updates and overviews on their goals, sales, revenue and employee performance, which is useful in decision making and problem solving. The insights also help them to provide better customer service, identify potential customers, plan work schedules for employees, investment, inventory management and marketing.

C. Benefits and Impacts of BI Application

The benefits of BI tools were evident in both organizations, particularly in terms of operational efficiency and enhanced customer satisfaction through better customer insights. Both companies have experienced substantial growth in recent years, which is visible in their bottom line as well as employee numbers. However, both interviewees pinpoint that their success in business is not exclusively because of BI tools application but rather a holistic and data-driven approach in overall decision making.

Furthermore, their customers are applying BI tools as well, making it possible to synchronize customer data with their internal data effortlessly and provide a faster and reliable service. Thus, both companies believe that their operational efficiency has increased through better overview of their supply chain and communication process has become effective, now that they have eliminated time consuming process of involving many communication channels.

D. Organizational Culture and Practice

Finally, the interviews shed light on the cultural shifts associated with BI adoption. Both companies reported a transition towards a more data-driven culture, where employees at all levels are encouraged to leverage BI tools in their daily practices. This cultural change is crucial for maximizing the potential of BI technologies, as supported by existing research.

There is increased awareness in using terms and terminologies that fit the customers' need and perception. With the BI insight, Peter and his employees at ELS have become conscious about words they use to describe their products appeal to the clients in their webshops instead of using technical specifications only, which may not be easily understood. He also mentioned that they keep an eye on which signage or texts are written in the vehicles their clients drive, so that they can match their clients' perception with the company's offer.

Similar pattern was noted at DVA. Their Salesmen use BI insights not just to sell the clients what they need at the moment but also to prepare the clients what they might need in the next step, so both DVA and their clients are several steps ahead with logistics planning and warehouse optimization, enabling company's supply chain agility.

V. DISCUSSION

Both case companies have experienced success and significant growth with the application of BI tools but they also acknowledge that one cannot single out BI tools but rather combination of various factors for their successful performance. However, the data driven focus has been a determining factor for both companies internally as well as externally with their clients.

Our findings confirm previously identified CSFs and emphasize the significance of holistic approach in decision making and strategic planning but the decisions will only be good, if the basis, i.e., data quality is good and is accessible to those involved in the process. Similarly, access to technical expertise such as system developers plays an important role.

Furthermore, organizational culture and practice evolve together with the use of BI. The case companies supply specialized products and have specific clients but being able speak/communicate in the language that is understandable to customers gives clear advantage. The ability to be proactive in planning not just own future plans but predicting the future needs with clients and being strategic give the companies a competitive edge, leading to more successful implementation of BI tools.

Both interviewees are adamant about the positive side of applying BI and did not reveal any problematic issues. This could of course be because there is no such issue and any challenge and obstacle they encounter, get easily solved. Perhaps being successful business, it is difficult to bring negative issues forward for case studies. However, it could as well be the pitfall of this research that the case companies perform well in general and are growing continuously. Had we looked into cases with poorer performance or history, our findings might have been different. Although finding managers willing to share stories of failure could be a challenge in itself.

Similarly, both interviewees are responsible for and are experienced users of BI, so they have good understanding and know-how of BI tools, can easily seek solutions when faced with problems and are also decision makers. The picture might have been different, if the interviewees were less experienced or are directly or indirectly influenced by the decisions made but are not involved directly.

VI. CONCLUSION

This research examines the CSFs for applying BI tools in the distribution sector through case study involving two SMEs catering to B2B clients within building and construction industry. It confirms existing discussions regarding the success factors in implementation of BI technologies and its perceived benefits, such as overall decision-making and strategic planning, data quality, benefits and impact of BI and organizational culture. But the CSFs discussed in this research cannot stand alone for harnessing the benefits from BI. The emphasis must still be on a data-driven, holistic approach towards decision making and strategic approach.

The insights gained will contribute to a deeper understanding of how organizations can effectively apply BI to drive performance and foster a culture of continuous improvement. Further research involving companies with negative experiences of applying BI could shed more light on how organizations can learn what not to do and not just what to do to get better success and competitive advantages of applying BI tools in the overall organizational development. Similar studies involving big, multinational companies could build upon the knowledge providing a list of Do's and Don'ts for integrating BI tools to benefit and succeed from such digital transformation.

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AURORA: An Automated Database Schema Change Logging System

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***Abstract*— Database schema changes pose a critical challenge when updating Computer Information Systems (CIS) since they require careful synchronization between codebase updates and the database. Traditional approaches to schema evolution often lack automated tracking of schema changes, leading to duplicated coding, data loss, inconsistency, and increased downtime. This paper presents AURORA, an automated solution that captures the Data Definition Language (DDL) and Data Manipulation Language (DML) operations performed by the data designer. The captured data is then used to drive client-side database schema upgrades. By leveraging Database Management System (DBMS) event triggers, this system ensures that any relevant DML and DDL events are logged and used for the generation of a schema upgrade script. This script includes the schema changes performed by the data designer and the respective pre and post data checks to ensure database consistency and integrity at the client's database. This client-side script also includes a rollback mechanism to reverse a schema upgrade in the case of failure. AURORA was evaluated through a set of real-world scenarios which highlighted its practicality, coverage and validity.**

Keywords-schema evolution; computer information systems; databases; software deployment; software upgrades.

I. INTRODUCTION

A Computer Information System (CIS) implementation, e.g., codebase and database structures, is static in contrast to the dynamic environment in which its clients operate. Therefore, for a CIS to remain relevant for its clients, it is subject to updates which are orchestrated by the software provider [1][2]. However, if an application update includes database changes, an issue arises since the client's database must undertake the appropriate script to migrate it to the desired state while ensuring that its data is preserved. This script must be distributed to all clients alongside the updates to the application program and must be validated at each client-side database prior to running the updated version of the software. This local action is required as most applications have a portion of their codebase with a hard-coded representation of the schema in use [3].

Generating these database upgrade scripts is challenging since, if the Structured Query Language (SQL) queries performed on the database during development are not explicitly logged, they are lost. As a result, this leads to the tedious and time-consuming task of redoing the queries to generate a change script for the schema upgrade. Other challenges include ensuring that each change construct has an undoing action, in case an update cannot proceed at the client, and that schema changes that cause data loss, e.g., delete operations, are supported with redundant structures to ensure that these operations remain undoable during the upgrade process.

Moreover, one must account for any additional artefacts that a client has added independently of the software provider. For example, a view created on the old schema can become nonsensical when an upgrade script changes the base tables it depends on.

Upgrades to database schemas are not taken lightly. Firstly, there is the issue of application availability, i.e., the system is offline whilst a client is executing an upgrade. Secondly, an upgrade must not purge nor make data unreachable for the client. Thirdly, errors during the upgrade process can leave the database in an inconsistent state. Therefore, an adequate mechanism to roll back the database to a stable checkpoint is required. An example of an upgrade going wrong is the case of Revolut's authentication system [4] where the deletion of, what seemed to be, an unused table column, caused the entire authentication system to fail.

AURORA addresses the issue of generating database upgrade scripts by implementing a mechanism that automatically tracks the Data Definition Language (DDL) and Data Manipulation Language (DML) operations performed by a data designer. This automation also generates the respective pre, post, and undoing code fragments for the captured DDL and DML constructs.

AURORA also aims to make it easier for the client-side execution of a schema upgrade by generating an upgrade script that only requires minimal manual database administrator (DBA) intervention even when the upgrade process fails, or the upgrade process cannot proceed. Moreover, the client-side script keeps the client's existing data and adapts it to the new schema, and it also allows the client's DBA to easily reverse a database upgrade, therefore reducing downtime and addressing recoverability.

At the software provider, AURORA tracks changes to schemas, tables (for both DML and DDL changes), views, functions, and table triggers. To achieve this, AURORA requires the DBMS to support DDL and DML triggers since these are the mechanisms which are used to track the schema changes. Any application code that is external to the database, e.g., front end code, is outside the system's scope.

This paper is divided into six sections. Section one provides the reader with an introduction to the area, its challenges and the work in this paper. Section two provides

 ISBN: 978-1-68558-265-4

the reader with an overview of some of the relevant literature in the area, and a few existing vendor-specific solutions. In Section three, the requirements and design of AURORA are presented, and Section four details the implementation. Section five includes a real-world evaluation of the system, and Section six concludes this paper.

II. BACKGROUND & LITERATURE REVIEW

Version Control (VC) software allows development teams to manage and keep track of their source code revisions [5], allowing them to access, integrate and back track to older versions of the code as needed. VC has been used to track changes in code through tools like Git [6] and to track document and file updates through cloud storage solutions like OneDrive [7], Google Drive [8] and Dropbox [9]. Moreover, numerous tools exist to perform VC on the database during schema evolution [10]–[15].

Schema evolution in database design involves the modification of a schema artefact through a sequence of schema changes (see Table 1) while retaining the consistency of existing constraints and data [16]. Schema evolution implies codebase development (since queries that depend on the changed artefacts need to be examined for continued validity), but not all codebase development results in schema changes. Software providers deploy application program upgrades to their clients much more frequently than database updates since the latter are usually delayed and performed in a batch. This occurs due to the sensitive nature of schema changes and the fact that, as discussed, a schema change results in an application program update.

Apart from the application's codebase, schema evolutions also effect the Extract, Transform and Load (ETL) [17] scripts which are used to generate Online Analytical Processing (OLAP) systems and the global schema of a multi-database system. The freshness rate of Hybrid transactional/analytical processing (HTAP) systems is also determined by the recency of the schema in use [18]. Therefore, understanding how a schema has evolved over time is crucial to ensure that these scripts and systems are adequately updated with the newest version of the schema.

To better manage schema evolution during application development, Curino et al. developed PRISM [2][19] which allows developers to specify schema changes through Schema Modification Operators (SMOs). PRISM then uses these SMOs to update a schema, and its data, to the target version. PRISM can also re-write a sub-set of queries to match the target schema, ensure data preservation and create undo operations from each SMO [19]. However, PRISM limits the development team to using the provided SMOs, which, as highlighted by Herrmann et al. [20], is not a complete coverage. Moreover, the development team must manually audit any changes performed on the database through these SMOs since an SMO can result in many DML and DDL operations on the database. Finally, the development team must manually write these SMOs, and PRISM does not consider additional database constructs which were added by the client (e.g., views and functions).

In addition, numerous commercial solutions [10]–[12] exist to manage schema evolution with Oracle [13], IBM [14] and Microsoft [15] each having their own tools to handle schema changes on their own database management systems (DBMS). However, the development team must still manually log the queries executed on the database as the 'diff' [21] comparison-based functionality provided by these tools does not consider the changes that happened in between two schema versions in a similar notion to performing a diff between two text files.

TABLE I. A SUBSET OF SCHEMA CHANGES WHICH TARGET A TABLE

Granularity	Description
Add Table	
Table Level	With Indexes
	Without Indexes
Attribute Level	Without Constraints
	With Constraints
Purge Table	
-	Drop Table
-	Covert table to many tables, e.g., 1-to-Many relation
-	Purge table and move its data to another table
Amend Table	
Table Level	Add/Alter/Delete Comment
	Add/Alter/Delete Indexes
	Enable/Disable Triggers
Attribute Level	Change Datatype
	Add/Alter/Delete Constraints

Given two database schemas, the schema diff algorithm returns the SQL statements that must be executed to synchronize both schemas. However, this algorithm does not consider the steps taken to arrive at the target point. For example, consider the schema change presented in Figure 1. The algorithm would generate the SQL operations found in Figure 2. These operations would result in the loss of all user addresses since the 'Address' column is dropped without copying its data to the new table. Moreover, the schema diff algorithm links the 'AddressID' column in the destination schema to the 'AddressID' column of the 'Address' table found in the source schema being compared, i.e., `sch_b`, rather than using the newly generated 'Address' table in the destination schema, i.e., `sch_a`, which does not represent the developer's original intention.

Another technique to perform schema evolution is temporal versioning which stores the entire schema for each schema change that occurs. This requires more annotations but has powerful version reasoning constructs that allow the DBA to move from one version to another and it also allows for a few concurrent schema versions, e.g., possibly depicting different functionalities.

A delicate part of the management of schema changes is their recording, and this is mostly developer input. A tenable method to automate the recording of schema changes is to trigger actions on DDL constructs, as is done with DML operations. In PostgreSQL, this can be achieved through event triggers [22]. Event triggers can be fired either before

or after a DDL event has occurred and they can also be triggered by specific DDL events, e.g., only on delete operations. This mechanism enables the automated recording of schema changes without requiring any further explicit action from the developer.

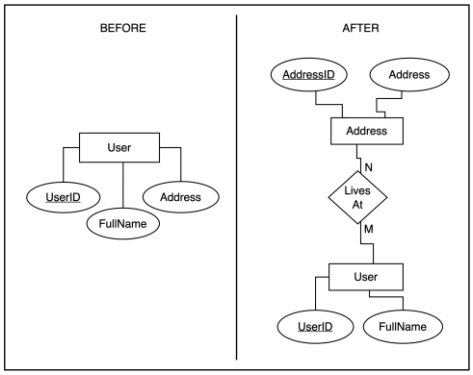

Figure 1. A schema change with data loss when using a schema diff algorithm.

```
CREATE TABLE IF NOT EXISTS sch_a."Address"
(   "AddressID" text NOT NULL PRIMARY KEY,
"Address" text NOT NULL );

ALTER TABLE sch_a."User"
DROP COLUMN IF EXISTS "Address";

ALTER TABLE sch_a."User"
ADD COLUMN "AddressID" text NOT NULL;

ALTER TABLE sch_a."User"
ADD CONSTRAINT "Users_AddressID_fkey"
FOREIGN KEY("AddressID")
REFERENCES sch_b."Address" ("AddressID");
```

Figure 2. The SQL queries generated by a schema diff algorithm (found within pgAdmin [23] version 8) for the schema change in Figure 1.

Software vendors can distribute code changes over-the-air, e.g., through package managers or Docker [24], or through manual techniques [25], e.g., file transfer. When run at the client, the database upgrade script generated by the vendor must do the necessary pre-checks (to ensure that none of the changes affect the client's data), schema updates, and post-checks (to ensure that no data was lost during the upgrade process). If any pre-checks fail, the database is not compatible with the upgrades defined by the vendor and, if any post-checks fail, this implies that the schema changes resulted in an inconsistent database state and the old state needs to be restored.

III. REQUIREMENTS & DESIGN

A software vendor that develops database-centric application programs requires a system that automatically transcribes schema changes over the database in an upgrade script. This script must then be packaged and applied to the client's database when the application program is upgraded at the client. The software vendor also requires that the schema change has its respective undo action sequence in case the upgrade needs to be reverted. Finally, apart from creating the upgrade and undo script, the system must also ensure that these changes were performed correctly on the client's database. If the client's database instance loses consistency, any data is lost from the client's database, or the update is not what was expected, then the client's database needs to be recovered to the state before the process started.

The software vendor is accepting that the system is based on a single DBMS, e.g., PostgreSQL, and that a reasonable subset of SQL's DDL and DML operations are available. Furthermore, the system must maximize the facilities provided by the DBMS, i.e., programming interfaces and data dictionaries. Moreover, the script generated is to have adequate security profile requirements and should be executed efficiently on client-side set-ups. Finaly, data consistency, and availability need to be catered for as well.

Schema changes can be captured in a few ways. One approach is to use a rule-based system, based on triggers and event triggers, to capture the DML and DDL queries generated by the data designer. This method attaches DDL triggers to the schemas that need to be tracked and DML triggers to the tables that need to have their data changes tracked. Once a trigger action is fired, it stores the difference in metadata between the current version and the proposed change, thus encoding schema evolution [16] through trigger action and the underlying data dictionary.

Another approach is to use a schema diff algorithm. This algorithm could be used in one of two ways – one can either compare the initial schema with the final schema, after all the changes have been done, or one can apply the schema diff algorithm incrementally after each schema change. The former provides a succinct upgrade script but loses the actions that happened in between the major versions while the latter essentially generates the SQL query which was input by the data designer.

When comparing the two approaches, it was decided to adopt a rule-based system for AURORA. Such a decision was taken as, to execute the schema diff algorithm incrementally after each schema change, a system of DDL and DML triggers is still required. Moreover, as discussed in Section 2, the queries generated by the schema diff algorithm are not adequate as these may lead to erroneous schema upgrades.

PostgreSQL has DDL triggers and makes use of two data dictionaries, the SQL `information_schema` and the Postgres-specific `pg_catalogue`. AURORA uses the `pg_catalogue` as this allows it to interpret implementation-specific queries that the database designer may run.

Moreover, the `pg_catalogue` allows the system to reference objects using a robust naming scheme across the instance, i.e., the OID. Having a robust naming scheme is crucial since it allows the system to accurately track an object throughout its lifespan, from creation to deletion. One must note that database objects can be renamed, and they may also be dropped and re-created using the same name. Therefore, the object's schema-qualified name, which the `information_schema` uses to identify objects, is not adequate to identify an object throughout its entire lifespan.

IV. IMPLEMENTATION

AURORA was implemented and tested on PostgreSQL 15. At the software vendor, the application's database includes a dedicated `version_control` schema which includes all the tables and functions which are needed to track the DML and DDL changes performed on that database. DDL changes are tracked using event triggers while DML changes are tracked using triggers which are automatically attached to the version-controlled tables.

As depicted in Figure 3, when the database designer enables the system, a snapshot of all the tracked objects in the database is taken. Then, whenever a DML or a DDL query is executed, a snapshot of the data dictionary entry of the effected object(s) is re-taken. Each time a snapshot is taken, a new version of the database is said to have been generated.

When doing DDL operations, AURORA uses the OID provided by the event trigger to get the object that was directly modified; however, it also checks each database object individually to determine if any other object has been modified as a side-effect of the DDL operation. This is done by generating and comparing the SHA1 hash of each object's metadata as found in the data dictionary and in the object's latest snapshot in the system. If the hashes don't match, then the object has been modified, and a snapshot of the object is taken. If the hashes match, then the operation does not need to be recorded.

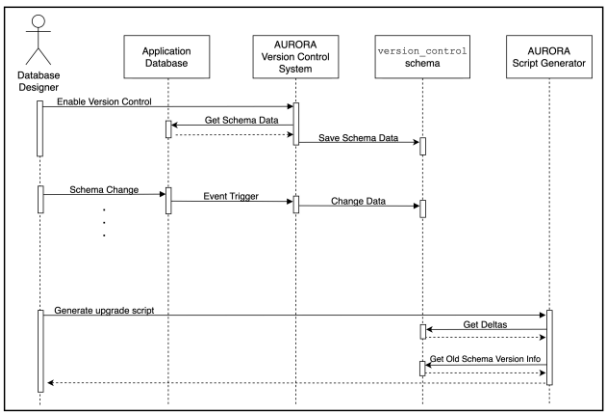

Figure 3. A UML Sequence Diagram depicting how AURORA is used by the developers.

With regards to DML operations, AURORA keeps a snapshot of the old and new version of the modified record(s) in JSON format. This allows all DML changes to be stored at the same table, even though each table has its own set of attributes.

Once the database designer performs all the changes to the schema, they can then use the provided Python program (referred to as the 'script generator') to generate the SQL upgrade script from the snapshots captured. The DBA at the client can then use another Python program (referred to as the 'script executor') to execute the SQL upgrade script on their database instance.

Given a specific range of versions, the script generator gets all the snapshots in that range in JSON encoding, and it compares each snapshot with the last snapshot of that object using a JSON 'diff' algorithm. Depending on the attributes that have changed between the snapshots, it then tries to generate an SQL query like the one that was executed by the data designer. This program also generates the respective undo queries to reverse the operation. This allows the DBA at the client to reverse the upgrade without needing to restore an entire database backup since this extends downtime.

Once the upgrade script is created, the script generator then generates a list of database objects that the script executor should find in the client's database instance. This list along with the SQL upgrade script and the script executor program are provided to the client to allow them to upgrade their database instance to the latest version.

The script executor is split up into three parts: the pre-checks, the execution of the SQL scripts and the post-checks. As part of its pre-checks, the script executor uses the list of objects generated by the script generator to ensure that the state of the client's database is as expected; otherwise, the SQL upgrade script will not be compatible with the database and might cause unexpected results.

If additional constructs are found in the database, e.g., views and functions that are created by the client, and they do not depend on any object that will be modified by the generated SQL upgrade script, they are left untouched. However, if the pre-checks determine that these objects will be affected by the upgrade script, the process is stopped and the user is informed that these objects need to be maintained for the script to run.

Before running the upgrade script, another pre-check is performed to ensure that any new integrity constraints do not affect any of the client's data in the database. If this is the case, the client's DBA is asked to remove the violating data from the appropriate table.

Once all the pre-checks are done, the script executor gets the number of records in all the tables and a hash for each record is generated. This information will then be used at the end of the upgrade to ensure that no data loss occurred (apart from that which was expected).

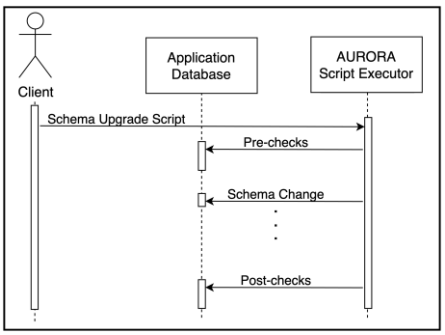

Figure 4. A UML Sequence Diagram depicting how AURORA is used on the client-side.

Before starting the upgrade itself, the script executor generates a backup of the entire database. This is done to ensure that no data is lost if something goes wrong and the

database needs to be restored. Once the backup is generated, the script executor starts running the upgrade script on the client's database. As each query is being executed, an audit is kept of which queries were run. This allows the script executor to know which queries have been run and which reverse queries to execute if the upgrade fails. Once the upgrade is done, the script executor ensures that no data loss occurred based on the data recorded before the database was upgraded. This process can be seen in Figure 4.

To make it easier to reverse an upgrade, the script executor puts a 'tombstone' on any objects that need to be deleted. In this way, if a drop operation needs to be reversed, the tombstone is simply removed and the object, and all its data, is once again accessible.

AURORA's code was thoroughly tested with standard methods to ensure that it works as expected. Numerous DML and DDL queries with different variations were tested to ensure that the triggers were working as expected and to ensure that the system was correctly logging the objects' changes from the data dictionary. The script generator was tested by generating a set of JSONs, which represented both valid and invalid schema changes, and ensuring that the correct output, i.e., an SQL forward and backward query or error, is provided by the program. The script executor was tested by ensuring that any additional constructs generated by the client are detected, that any missing database objects are detected, that the script can adequately undo its actions if an error occurs, and that any unexpected data loss is detected.

V. EVALUATION

AURORA was evaluated by simulating how it would be used in real-world scenarios. This was done by performing a set of schema changes on one database to simulate the changes performed at the vendor and then running the resulting script on another database to simulate the client's context. The goal of this evaluation was to ensure that:

1. The client's database ended up in the same state as that of the vendor, i.e., the vendor's DML and DDL operations were correctly recorded and executed;
2. All the client's data, in the unchanged schema objects, is preserved;
3. If the client's database has additional constructs which were created by the client (and which do not depend on the objects modified by the vendor), these constructs are preserved after the upgrade.

This evaluation was designed to cover as much of the schema changes that are tracked by AURORA. This was achieved by running the DML and DDL operations needed to generate the Scott schema [26], by going from version 7d4ca07595c6 [27] to 193312356621 [28] of the WikiMedia database and by upgrading a custom-made database [29].

The Scott schema was used to ensure that AURORA can handle a basic set of CREATE TABLE, ALTER TABLE and INSERT commands. The WikiMedia schema was used to test AURORA with a real-world database upgrade. Finally, a custom-made database schema was used to evaluate AURORA's performance on the remaining database objects that were not considered with the previous cases.

VI. CONCLUSION

Version Control plays a crucial role in software development; however, its support in databases is lacking as, although numerous systems exist to perform some form of version control on a database, schema changes need to be manually recorded by the development team. This increases the risk of missing key operations while creating the database upgrade script. Therefore, this paper introduced AURORA which automatically tracks the DDL and DML operations performed on a database. Using this tracked data, the system can automatically generate a database upgrade script along with a set of undo queries to rollback unacceptable upgrades. The script generated is then given to the client to apply the changes to their own database, reducing downtime while ensuring data integrity throughout the upgrade process.

AURORA was implemented on PostgreSQL, and it has been shown to reliably handle schema evolutions. This system's techniques offer a significant advantage when compared to techniques based on a schema diff algorithm since this system offers a finer granularity of changes. It also represents a significant step forward in database version control as it has the ability to automate schema evolution while minimizing downtime and preserving data consistency, making it a valuable tool for both developers and clients. As a result, AURORA can effectively improve the workflow and the quality of software deployments for both the software house and its client.

Unlike Git, which is a distributed and decentralized version control system [6], AURORA only works on a centralized database. If decentralized database support is required, a causal consistency [30][31] mechanism is indicated as it ensures a partial ordering between a schema change and any operation that depends on it while providing reasonable performance.

AURORA does not modify the DDL and DML operations that were executed by the software provider. As a result, there is the possibility that the upgrade script includes redundant DDL and/or DML operations. For example, if the data designer creates a table, deletes it and re-creates it with the same name (without doing any other actions to the table), the first two create and delete operations can be omitted from the script as their net effect is nil. Future work involves optimizing the upgrade script to address such redundant processes.

Lastly, this system integrates with previous works such as PRISM. By modifying AURORA to automatically generate the Schema Modification Operations based on the DML or DDL operations performed, one would be able to take advantage of PRISM's features, such as its query re-writing facilities. Further query re-writing facilities can also be provided to re-write SQL specific constructs, e.g., the SQL query in a subset of Common Table Expressions (CTEs). However, even if such query re-writing facilities were provided in AURORA, the queries (to be re-written) would have to be provided explicitly by the developer since automatically identifying the SQL queries in the application's codebase would require a full scan of the entire

source code and would require numerous heuristics, e.g., to differentiate a string which is holding an SQL query against a string which is holding a user prompt. Moreover, the application may generate SQL queries during runtime, meaning that the application's codebase would only have partially written SQL queries, which cannot be re-written.

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How Does IT Governance Improve Firm Performance? A Dynamic Capabilities Perspective

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Abstract— **While researchers agree that IT Governance (ITG) positively affects business performance, there is still a lack of consensus on how IT Governance improves firm performance. Many studies have used the Resource-Based View (RBV) to analyze and interpret this question. However, RBV offers a limited perspective on firm performance by associating it with static resources and does not capture the role of dynamic capabilities in enabling firms to adapt and succeed in evolving environments. This paper argues that ITG should be conceptualised as a combination of ordinary and dynamic capabilities, wherein dynamic capabilities improve and support ordinary ones, ultimately maximizing business performance. Based on a comprehensive literature review, this paper provides a deeper understanding of how ITG contributes to firm performance by breaking down ITG into specific capabilities rather than treating it as a single concept. The model extends RBV theory by demonstrating how combining dynamic and ordinary capabilities enhances an organization's ability to both innovate and sustain competitive advantage.**

Keywords- IT Governance (ITG); firm performance; Dynamic Capabilities.

I. INTRODUCTION

While the importance of IT in organizations is uncontested, it represents significant spending for organizations and its costs are rising every year [1]. Increasing the value of IT investments is therefore crucial for firms to remain competitive in the marketplace. IT Governance (ITG) has gained attention in this regard. Indeed, companies that have good ITG reap up to 40% higher return on their IT investments [2] and could get an increase of up to 20% in profits [3]. While the literature seems to be adamant that ITG has a positive impact on firm performance, the reasons why and how are still unclear [4]. The objective of this study is thus to shed light on the question that has been asked many times, but has still not been answered in a satisfactory way, i.e., how does ITG improve firm performance?

In the literature, the impact of ITG on firm performance has often been studied using the Resource-Based View (RBV). Several authors argued that ITG is a valuable resource that can lead to sustainable competitive advantage and, therefore, to increased firm performance [5]. We argue that this conceptualization is problematic for two reasons. First, ITG is a complex construct composed of organizational structures, processes, and relational mechanisms [6]. Hence, considering it as a single concept limits our understanding of how it impacts firm performance. Second, RBV does not account for today's dynamic and competitive marketplace. Indeed, according to the theory, a firm that has a valuable resource acquires a sustained competitive advantage [7]. That said, good IT Governance is not just about "effective IT control and accountability, performance management and risk management" [8], but also about seizing opportunities and encouraging and leveraging "the ingenuity of all enterprise personnel in using IT" [3]. Hence, simply controlling IT, although a type of ITG, does not capture all the ITG's benefits. Instead of assuming what ITG entails, we must be able to distinguish its different capabilities and the different effects that they can have on firm performance. Furthermore, because of the increasing interest in the importance of organizational agility, firms can no longer settle simply on past traditional ITG mechanisms.

To overcome these limitations, we adopt a dynamic capabilities perspective, which is referred to as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" [9]. We suggest breaking down ITG into two groups of capabilities, i.e., ordinary and dynamic capabilities, and studying the impact of each of those groups on different dimensions of firm performance. We therefore adopt a theory building approach to synthesise the literature on IT Governance and develop a new conceptual framework on the impacts of ITG on organizational performance.

The paper is structured as follows. In the second section, we establish our definition of IT Governance and show how previous authors have linked ITG to firm performance. This theoretical background leads to the third section of the paper, where we define dynamic capabilities, show how the concept has been linked to ITG in the past, and discuss the limitations of previous research. The fourth section presents our conceptual model and hypotheses, as well as ways to validate our model. Finally, we conclude by assessing the implications of our work for organizations and future research.

II. THEORETICAL BACKGROUND

A. IT Governance (ITG)

ITG was introduced in the literature nearly three decades ago [10]. Since then, it has been defined in a number of ways and there is still no shared understanding of the construct in

the literature [1]. ITG has been defined in numerous ways, including but not limited to: 1) "the strategic alignment of IT with the business such that maximum business value is achieved through the development and maintenance of effective IT control and accountability, performance management and risk management" [8], 2) "the firm's governance mechanisms that enable both business and IT people to execute their responsibilities in support of IT-related decision making and the creation of business value from IT-enabled business investments." [11], and 3) "the capacity of top management to control the formulation and implementation of the IT strategy via organizational structures and processes that produce desirable behaviors, which will ensure that IT initiatives sustain and extend the organization's strategy and objectives" [12].

Some authors [1][2] use Weill's [3] definition by describing ITG as a "framework for decision rights and accountabilities to encourage desirable behaviour in the use of IT". Some also refer to specific frameworks used in the industry, such as COBIT or ISO/IEC 38500 [5][13]. Buchwald, Urbach and Ahlemann [10] add that "ITG refers to an actively designed set of mechanisms that encourages behaviors consistent with the organization's mission, strategy, and culture.". Huang, Zmud and Price [14] also add that "the goal of IT Governance is to direct and oversee an organization's IT-related decisions and actions such that desired behaviors and outcomes are realized".

According to Kude, Lazic, Heinzl and Neff [5], ITG is composed of IT roles, IT groups, IT processes, and relational capabilities. Similarly, Webb, Pollard and Ridley [8] mention structures, control frameworks, and processes. Most agree that it is composed of organizational structures, processes, and relational mechanisms [1][4][6][15]. Some authors also describe the decision domains in which ITG is concerned. They report IT principles, IT architecture, IT infrastructure strategies, business application needs, and IT investments [2][3][8][15].

In this study, we will refer to ITG as the integrated set of organizational structures, processes, and relational mechanisms that enable to direct and oversee an organization's IT-related decisions and actions such that desired behaviors and outcomes are realized [14][15].

B. IT Governance and firm performance

Models theorizing the relationship between IT Governance and business performance are scarce and they all agree that ITG has a positive impact on firm performance. Some studies look at ITG antecedents to try to explain the effect of ITG on firm performance. For instance, Bradley et al. [12] study the effect of the level of CIO structural power, the degree of mutual participation between IT and other lines of business, as well as the degree of entrepreneurial culture on ITG in hospitals. Jewer and McKay [16], for their part, examine the impact of board attributes and organizational factors on board ITG. More specifically, they consider the proportion of insiders, the board size, and the IT competency of board members, as well as the organization size, its age, and the role of IT in the organization. While these studies bring insight into what could affect ITG, they don't help us understand how ITG can improve firm performance.

A significant portion of the literature examines the relation between ITG and business/IT alignment. While some stop at the effect of ITG on alignment [17], others argue that IT alignment in turn leads to improved business performance [4][18]. There is in fact a substantial number of studies showing how alignment can lead to increased performance [4]. Several mediators of the relation between ITG and firm performance have been identified. To name a few, resource relatedness – defined as the "usage of common IT resources and common IT management processes across business units" and business process relatedness – defined as the "usage of common business processes across business units" [1], strategic alignment [4], IT capability – defined as the "firms' ability to innovatively implement and deploy IT resources to obtain IT/business alignment and create competitive advantage" [11], and IT operating capability – defined as "the ability of a firm to effectively and adequately use IT tools and functions to support ordinary processes and operations" [19].

Some authors also explain the relationship between ITG and firm performance by studying the effect of moderators. For instance, Liu, Turel and Bart [20] consider the board governance style and the environment dynamism. They discover that while an authoritative governance style, which refers to a high engagement from the board in monitoring and advising roles, has a positive impact on firm performance, it is not the case in dynamic environments. The effect of both the need for fast and reliable IT and the need for new IT are also studied by Turel and Bart [13]. These authors found that the two variables led to a higher level of ITG enactment at the board level, which in turn had a positive effect on perceived organizational performance. However, their moderating effect on the relation between ITG and organizational performance is not supported, giving us no further understanding of how ITG impacts firm performance.

Huang, Zmud and Price [14] go in more depth and study the effect of two ITG practices, i.e., senior management involvement through IT steering committees and IT Governance communication policies. One of their key findings is that employing formal steering committees and using a greater number of communication channels, as well as the use of electronic channels, are both successful practices. However, those results provide only limited insight into how ITG increases firm performance. Moreover, the data used in their study is limited and calls for further research to generalize their findings [14].

Regarding the measure of firm performance, the majority of studies considered one or more financial indicators, such as return on investments, net profits, or management perceived financial performance [1][4][13][16][19][20]. While some studies examined other aspects, such as the firm's reputation or the frequency of new product or service introduction, the effect of ITG is generally examined on performance as a whole, with no distinction between the different measures of performance [1][16].

Most studies investigating the link between IT Governance and business performance do so using RBV [1][4][5][11][13][19][20]. RBV states that certain resources

possessed by an organization are a source of competitive advantage and that they can lead to sustained superior performance. To do so, a resource must abide by four criteria, referred to as "VRIN", i.e., valuable, rare, imperfect imitability, and non-substitutability [7]. Indeed, resources must add value to the firm, not be prevalent among the firm's competitors, and be difficult to copy. It is also important that no other resource could allow a competitor to achieve the same performance.

A recent development in the literature pertains to the emergence of a new approach to IT Governance: Agile Governance (AG). This concept emerged in the early 2000s and was initially associated with software development governance, given its connection with the Agile project management method [21][22]. However, the movement has since been linked with ITG [21][22][23][24][25]. This innovative approach to governance aligns with our conceptualization of the construct, as agility is inherently dynamic. Agility is linked to several benefits, including a reduction in lead times, an enhancement in quality and added value, an increase in success rates, and a more efficient decision-making process. These benefits collectively contribute to enhance the competitiveness of organizations [21][22][25]. According to Vaia, Arkhipova and DeLone [24], agility is defined as a dynamic capability that describes the ability to sense and respond to environmental change. In their article, they present an analysis of the extant literature and case studies, demonstrating how traditional approaches to ITG regarding structures, processes, and relational mechanisms can either amplify or hinder agility. In contrast, Zhen, Xie and Dong [25] employ the concept of IT ambidexterity as a capability intricately linked with IT Governance, with the objective of enhancing and encouraging organizational agility. They present ambidexterity as the firm's capacity to simultaneously leverage existing IT resources while exploring new ones. Vejseli, Rossmann and Garidis [26] also make an interesting contribution by studying the indirect impact of both Agile ITG mechanisms and Traditional ITG mechanisms on firm performance through Business/IT alignment.

III. PROBLEMATIZATION

While the literature demonstrates the positive impact of ITG on business performance, the mechanisms involved remain unclear. Yet, in order to increase the benefits gained by ITG, we need to reach a better understanding of how it improves business performance. As we mentioned, the impact of ITG on firm performance has mostly been studied using RBV. Under this theory, authors argue that ITG is a valued organizational resource that leads to firm performance. However, as we noticed, ITG has been conceptualized in various ways in past studies. Both the definitions of ITG and the way it is measured are not consistent in the literature. Indeed, while some only measure the simple presence of an ITG in an organization, others describe the components of ITG without addressing what are the effects of those specific components on business performance [1]. Since ITG is a complex construct, considering it as a single resource limits our understanding of how it affects firm performance. Indeed, since ITG refers to different types of organizational structures, processes, and relational mechanisms [1][4][6][15], it would be more appropriate and insightful to consider the different capabilities shaping ITG, as well as the different effects of each of those capabilities.

Furthermore, using only RBV is not appropriate anymore considering the current environment. Indeed, RBV is static and does not consider the fast-changing competitive landscape. According to RBV, a valuable resource will lead to a sustained competitive advantage [7]. However, today's dynamic environment calls for innovation. Even at the employee level, it is not enough for employees to simply perform their tasks anymore. Indeed, for a firm to remain competitive, employees are expected to "anticipate trends and needs" and to adapt their work accordingly [27]. Therefore, "effective IT control and accountability, performance management and risk management" [8] are not enough anymore to qualify a good ITG. Seizing opportunities and encouraging and leveraging "the ingenuity of all enterprise personnel in using IT" [3] is also crucial. Not only do we need to consider the different capabilities shaping ITG, we must also consider the type of capabilities. We might have an idea of what ITG should entail, but we cannot assume that every ITG in every organization does entail the same elements. This distinction can help us understand how ITG improves firm performance and how to maximize the potential benefits of ITG.

To take this into account, we suggest using the dynamic capabilities perspective. Dynamic capabilities have been defined as "the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments." [9]. While RBV assumes that a resource that allows a firm to have a competitive advantage at a certain point in time will lead to long-term performance if this resource is valuable, rare, inimitable, and non-substitutable, the dynamic capabilities perspective argues that the capabilities of the firm must change over time to remain relevant in the firm's rapidly changing environment [7].

Dynamic capabilities are also different from ordinary capabilities. While ordinary capabilities allow for the exploitation of the firm's current resources to ensure the continuity of day-to-day operations, dynamic capabilities allow for exploration [28]. Indeed, since dynamic capabilities focus on change, they permit firms to renew and reconfigure their resources and ordinary capabilities to innovate and explore "beyond their current market and technological domains" [28]. Therefore, they can also upgrade the firm's ordinary capabilities and increase the value that those ordinary capabilities generate [29].

To our knowledge, only two studies examining ITG have used the dynamic capabilities perspective before. First, Mikalef, Pateli and Van De Wetering [30]studied the relationship between IT flexibility and IT-enabled dynamic capabilities. They argue that a certain structural form of ITG, i.e., decentralized, moderates the effect of IT flexibility on IT-enabled dynamic capabilities. Second, Liu, Turel and Bart

[20] study board-level ITG specifically and state that it can be perceived as a dynamic capability because boards can reconfigure lower-lever capabilities, such as changing the structure of a department.

IV. Conceptual Model, Hypotheses and Future Research Avenues

A. Conceptual Model

Past studies using RBV conceptualize IT Governance as being one capability. We suggest that IT Governance is rather composed of different capabilities, which in turn can impact different dimensions of business performance. As already mentioned, IT Governance often refers to frameworks that help executives to control and ensure compliance with digitized business and mitigate IT-related risks and threats [5][13][15][20]. On the other hand, IT Governance is also described as supporting the creation of business value [8][11]. It raises IT opportunities for executives [20] and "encourages and leverages the ingenuity of all enterprise personnel in using IT" [3]. According to Weill [3], good IT Governance is both empowering and controlling.

Taking this into consideration, we conceptualize IT Governance as being composed of two groups of capabilities (Figure 1): (i) dynamic capabilities (i.e., sensing, seizing and transforming capabilities) as well as (ii) ordinary capabilities (i.e., controlling and complying capabilities). Sensing is the ability to identify opportunities outside of the organization, seizing is the ability to mobilize the resources to capture value from those opportunities, and transforming is the ability to realign the organizational structure and culture [29]. They are conceptualized as a group because together, they form an iterative process. Therefore, we argue that all three are necessary to persistently capture value. The second group of capabilities refers to the ability to control and comply. Controlling has to do with determining how things should be, while complying has to do with the ability to meet the determined standards. Hence, those two capabilities go hand in hand. We consider those capabilities as ordinary capabilities. Indeed, their purpose is to "exploit the existing resource base to ensure continuity of current operations" [28], which is exactly how ordinary capabilities are defined in the literature.

As previously mentioned, it is important to distinguish both groups of capabilities because while the literature suggests that a good ITG has sensing, seizing and transforming capabilities, we cannot assume all firms are equally good at governing IT. Indeed, a firm that simply uses a framework such as COBIT engages in a form of ITG [5]. However, the use of such framework without dynamics capabilities will result in a failure to leverage all benefits associated with IT Governance. Moreover, considering ordinary capabilities as exploitative and dynamic capabilities as explorative, Qaiyum and Wang [22] raise the fact that exploitation and exploration are considered to be both important in the organizational ambidexterity literature.

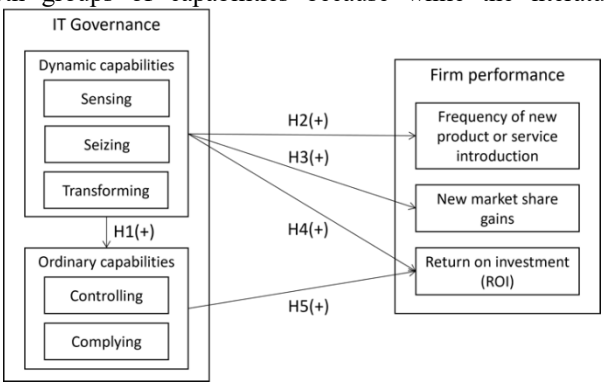

Figure 1. Conceptual Model.

B. Hypotheses

Consistent with past studies, we suggest that IT Governance has a positive impact on business performance. However, we argue that the capabilities constituting IT Governance will impact different types of business performance.

First, consistent with the premise of dynamic capabilities theory stating that dynamic capabilities can upgrade ordinary capabilities and increase their payoff [29], we suggest that the sensing, seizing and transforming capabilities will have a positive effect on the controlling and complying capabilities. Indeed, dynamic capabilities allow the firm to use and reconfigure its existing resources and capabilities in new and different ways [7]. For instance, they could drive an organization to reconfigure its organizational structure, thereby improving its ability to control its technologies, i.e., its controlling and complying capabilities. They could also give rise to innovative and more efficient operational processes related to controlling and complying capabilities. Those new operational processes would in turn increase the impact of ITG on firm performance and, more precisely, on ROI.

Hypothesis 1: Sensing, seizing and transforming capabilities are positively related to controlling and complying capabilities.

Second, dynamic capabilities call for change. They give the ability to use the firm's resources and capabilities in different ways and to reconfigure them [7]. They also allow for the creation of new resources and capabilities and are believed to procure the ability to innovate [29]. Therefore, we suggest that sensing, seizing and transforming capabilities will drive a firm's ability to innovate. We measure innovation by the frequency of new product or service introduction. An ITG that is only composed of controlling and complying capabilities will most likely focus on the firm's actual products and services and on mitigating the risks. It will thus probably miss the opportunity to innovate and introduce new products or services that could help increase the firm's performance.

Hypothesis 2: ITG sensing, seizing and transforming capabilities are positively related to the frequency of new product or service introduction.

Third, dynamic capabilities don't limit themselves to the exploitation of current resources. They also allow firms to "explore beyond their current market and technological domains" [28]. They give organizations a significant

competitive advantage by enabling them to respond to the fast and frequent changes in the market, going so far as to change the market themselves [29]. Moreover, their value goes beyond cost reduction and revenue increase [7]. Therefore, we advance that sensing, seizing and transforming capabilities not only improve ROI, but also allow firms to acquire market share gains.

Hypothesis 3: ITG sensing, seizing and transforming capabilities are positively related to market share gains.

Fourth, building on the dynamic capabilities' perspective, we suggest that sensing, seizing and transforming capabilities will also have a positive impact on ROI. Indeed, while ordinary capabilities help create value, dynamic capabilities will explore new ways to create value and ensure to adapt to the changing environment [9].

Hypothesis 4: ITG sensing, seizing and transforming capabilities are positively related to financial performance.

Finally, the controlling and complying capabilities will have a positive impact on financial performance, more specifically on return on investment (ROI). This hypothesis is consistent with the literature that found that ITG positively impacts a firm's financial performance. Drawing on RBV, controlling and complying capabilities will increase the business value of IT, which is either reflected as a reduction of the costs or an increase in revenues [7], measured hereby as the ROI.

Hypothesis 5: ITG controlling and complying capabilities are positively related to return on investment.

C. Future research avenues

To validate the proposed conceptual model, we suggest conducting surveys and using Partial Least Squares (PLS) method to analyze the collected data. We propose not only testing the effect of both dynamic and ordinary capabilities but also testing the individual effects of each of the five capabilities identified in the model.

Table I presents some ITG mechanisms found in the literature that could be used to operationalize each capability. First, *IT strategy committee at level of board of directors* and *Strategic information systems planning* would allow a firm to identify new opportunities. Second, *Architecture steering committee* and *Portfolio management* would assist the firm in addressing these new opportunities and integrating them into the firm's current landscape. Third, *Project governance methodologies* and *IT project steering committee* would enable the firm to conduct the necessary changes to its structures, processes, products and services, etc. Fourth, *IT Governance framework (e.g., COBIT)* and *IT budget control and reporting* are mechanisms meant to dictate what standards to follow. Finally, *IT audit committee at level of board of directors* and *IT steering committee* are structures that are meant to ensure that said standards are indeed followed.

TABLE I. CONSTRUCT OPERATIONALIZATION PROPOSITION

Capability	Proposed ITG mechanisms	Ref.
Sensing	IT strategy committee at level of board of directors	[31][32]
	Strategic information systems planning	
Seizing	Architecture steering committee	[32][33]
	Portfolio management	[32]
Transforming	Project governance methodologies	[32]
	IT project steering committee	[32][33]
Controlling	IT Governance framework (e.g., COBIT)	
	IT budget control and reporting	
Complying	IT audit committee at level of board of directors	[32], [33]
	IT steering committee	

V. CONCLUSION

It is well established in the literature that ITG leads to superior organizational performance. However, there is still a lot of uncertainty regarding the mechanisms involved. Indeed, studies on the subject often use RBV and conceptualize ITG as a single resource or capability, thus limiting our understanding of how ITG impacts firm performance. Moreover, RBV does not consider today's highly dynamic environment and does not capture the importance of dynamic capabilities in a good ITG.

To remediate those issues, we propose a conceptual model of the relation between ITG and firm performance based on the dynamic capabilities perspective. More precisely, we suggest that ITG encompasses sensing, seizing and transforming capabilities, as well as controlling and complying capabilities, and that each group of capabilities will have a different impact on different dimensions of firm performance, i.e., innovation, new market share gains, and ROI.

We believe that breaking down ITG into different capabilities instead of looking at it as a whole is a good step toward reaching a deeper understanding of how ITG improves firm performance and how organizations can maximize the potential benefits of their ITG. We therefore believe that this study could be beneficial in moving forward the research on the impact of ITG on organizational performance.

In terms of practical contributions, the proposed model raises the importance for organizations of having a holistic view of their ITG, rather than blindly relying on industry framework. To reap all the potential benefits of their ITG, some organizations may need to change their structure. For instance, they may benefit from putting an IT strategy committee at the level of the board of directors into place.

Nonetheless, in order to achieve a more profound comprehension of the model, further empirical research would need to be conducted to validate our hypotheses and build on the model.

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