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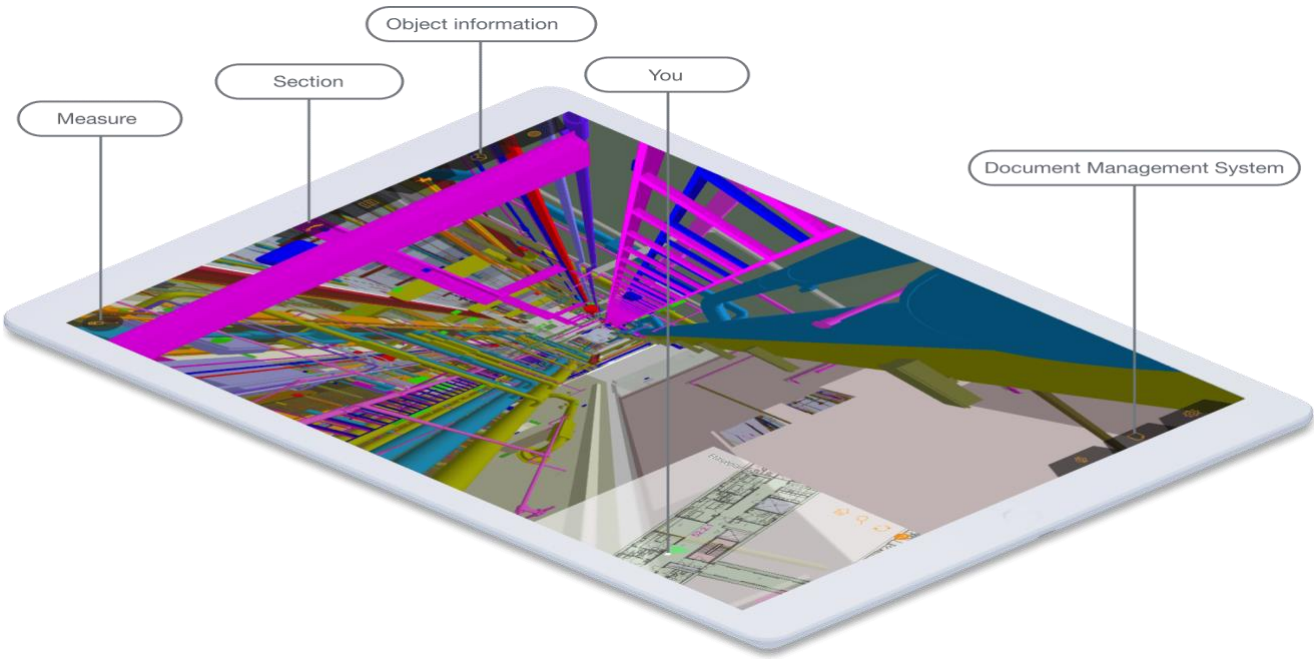

Enhancing Project Management and Inspection Efficiency through Advanced Data Integration in Construction Projects

Master's thesis in the master's program Design and construction project management

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ABSTRACT

The construction industry is increasingly adopting advanced digital tools to enhance project management practices, improve data accuracy, and streamline communication. This master's thesis investigates the integration of StreamBIM, a Building Information Modeling (BIM) software, with Power BI, a powerful data visualization and analytics tool, to enhance project management within the construction industry. The study focuses on a real-world project exploring the benefits and challenges associated with this technological integration. Through a detailed case study approach, including semi-structured interviews and thorough document analysis, the research identifies significant improvements in data management, inspection protocols, and overall project efficiency. The integration allows for advanced data filtering, customized visual representations, and the creation of interactive dashboards, which enhance the ability to monitor progress, identify issues, and make informed decisions. Key findings demonstrate that this integration not only improves the accuracy and timeliness of data but also facilitates better communication and collaboration among project stakeholders. The results highlight the transformative impact of integrating StreamBIM with Power BI, showing marked enhancements in the preparation and planning stages of inspections, standardization and automation of reporting processes, and overall quality control. The study concludes with recommendations for further improving digital tools in construction management, emphasizing the need for comprehensive training programs and the adoption of a model-based construction approach to fully leverage the capabilities of BIM and data visualization technologies. This research contributes to the body of knowledge on BIM integration, offering practical insights and solutions for industry professionals aiming to achieve more efficient and effective project management outcomes.

Key words: Building Information Modeling (BIM), Power BI, StreamBIM, Inspection, Data visualization

Integrera StreamBIM med Power BI för en förbättrad projektledning och besiktningsprocess i byggprojekt

Examensarbete inom masterprogrammet Design and construction project management

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SAMMANFATTNING

Byggbranschen adopterar i allt högre grad avancerade digitala verktyg för att förbättra projektledningspraxis, öka datanoggrannhet och effektivisera kommunikationen. Denna masteruppsats undersöker integrationen av StreamBIM, en programvara för byggnadsinformationsmodellering (BIM), med Power BI, ett kraftfullt verktyg för datavisualisering och analys, för att förbättra projektledning inom byggbranschen. Studien fokuserar på ett verkligt projekt och utforskar fördelarna och utmaningarna med denna tekniska integration. Genom en detaljerad fallstudieansats, inklusive halvstrukturerade intervjuer och noggrann dokumentanalys, identifierar forskningen betydande förbättringar inom datamanagement, inspektionsprotokoll och övergripande projekteffektivitet. Integrationen möjliggör avancerad datafiltrering, anpassade visuella representationer och skapandet av interaktiva instrumentpaneler, vilket förbättrar förmågan att övervaka framsteg, identifiera problem och fatta informerade beslut. Nyckelfynden visar att denna integration inte bara förbättrar datanoggrannheten och tidsaspekten utan också underlättar bättre kommunikation och samarbete mellan projektets intressenter. Resultaten framhäver den transformativa effekten av att integrera StreamBIM med Power BI, med tydliga förbättringar i förberedelse- och planeringsstadierna för inspektioner, standardisering och automatisering av rapporteringsprocesser samt övergripande kvalitetskontroll. Studien avslutas med rekommendationer för ytterligare förbättring av digitala verktyg inom byggprojektledning, med betoning på behovet av omfattande utbildningsprogram och antagandet av en modellbaserad byggnadsmetod för att fullt ut utnyttja kapaciteterna hos BIM och datavisualiseringstekniker. Denna forskning bidrar till kunskapsområdet om BIM-integration och erbjuder praktiska insikter och lösningar för yrkesverksamma inom branschen som strävar efter att uppnå mer effektiva och effektiva projektledningsresultat.

Nyckelord: Building Information Modeling (BIM), Power BI, StreamBIM, Inspection, Data visualization

Preface

We would like to express my deepest gratitude to all those who supported us throughout the process of completing this thesis.

First and foremost, we extend our heartfelt thanks to our supervisor, Mattias Roupe, for his invaluable guidance, constant support, and insightful feedback. His expertise and encouragement have been instrumental in shaping this research, and we are truly grateful for his dedication and patience.

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Lastly, we would like to thank all our colleagues and the academic staff at Chalmers University of Technology for their assistance and for providing a stimulating academic environment.

Thank you all for your support and encouragement,

Isaac Ali & Ashiq Ahmed, Gothenburg 2024

1 Introduction

The construction industry is continuously evolving, driven by advancements in technology that aim to enhance project management practices. One such technological advancement is Building Information Modeling (BIM), which has emerged as a pivotal technology, facilitating the digital representation of the physical and functional characteristics of buildings (Aghimien et al., 2022; Moradi & Sormunen, 2023). StreamBIM, a leading BIM software, provides a collaborative platform that aids in the management of construction projects. However, while StreamBIM offers substantial benefits, there is potential for further improvement through its integration with advanced visualization and analytical tools such as Power BI (Becker & Gould, 2019).

Construction projects are often complex, involving the coordination of multiple disciplines and the management of extensive data. Effective project management hinges on robust decision-making processes, clear communication, and efficient inspection protocols. Traditional methods, reliant on manual processes and paper-based documentation, often fall short in meeting these needs (Jensson, 2017). The integration of StreamBIM with Power BI promises to address these challenges by enhancing data accuracy, streamlining communication, and improving overall project efficiency.

In this master's thesis, the focus is to explore the integration of StreamBIM data with Power BI to elevate project management practices within the construction industry. Leveraging a real project with a leading project development and construction group, the aim is to uncover the benefits and challenges associated with this integration. The research is grounded in a series of interviews with project managers and an in-depth analysis of project documentation, enabling us to identify specific data visualization needs and preferences within the industry.

The integration of StreamBIM with Power BI promises to transform the way project managers interact with data, enabling them to visualize complex datasets in an intuitive and meaningful manner. This integration can help in identifying trends, spotting potential issues before they escalate, and making informed decisions that drive project success.

This thesis is structured as follows: firstly, a comprehensive literature review to contextualize the research within existing studies on BIM and data visualization in construction project management. Then, a description of the methodology, including the design and execution of interviews and the analysis of project documentation. The subsequent chapters present the findings, discussing the benefits and challenges of integrating StreamBIM with Power BI, and propose solutions to address identified issues.

The research aims to contribute to the body of knowledge on BIM integration with advanced data visualization tools, offering practical recommendations for industry professionals. By demonstrating the value of tailored visualizations, we hope to influence future practices in project management, leading to more efficient and effective construction project delivery.

1.1 Aim and Research Questions

This study aims to improve project management practices within the construction industry by integrating data from StreamBIM, a BIM software, into Power BI for advanced visualization and analysis. This integration aims to enhance decision-making processes, communication, inspection protocols, and overall project efficiency by providing tailored visualizations that empower project managers with actionable insights derived from StreamBIM data. The study leverages a real project to investigate the benefits and challenges associated with connecting StreamBIM data to Power BI.

The following research questions will be investigated as a complement to the aim:

1. *What are the benefits of integrating StreamBIM data with Power BI for construction project management?*
2. *How does the integration of StreamBIM data with Power BI enhance data visualization and filtering capabilities for construction project management?*
3. *What methods can be employed to improve the inspection process in the construction industry?*

2 Background

2.1 Innovative Project Management

Worldwide, the construction industry is a major driver of economic growth because it is essential for building infrastructure, homes, and cities. Despite the importance of project management, the industry has struggled with it for a long time, which has led to schedule delays, cost overruns, and degraded quality. From higher costs to delayed schedules for vital infrastructure projects, these problems affect project stakeholders and society at large (Marcellino et al., 2023).

Construction projects are notoriously difficult to complete because of the many moving parts, complicated supply chains, and interdisciplinary nature of the work involved (Nam et al., 2016). Due to the ever-changing nature of current construction projects, traditional techniques of project management such as manual processes, fragmented communication, and restricted data visibility are ill-equipped to handle them (Nguyen et al., 2018).

Consequently, project managers frequently encounter challenges when trying to coordinate tasks, reduce risks, and make educated decisions on the fly. Efficiency, innovation, and sustainability are of the utmost importance in the construction sector due to the highly competitive nature of the industry (Yalcinkaya et al., 2013). Within this framework, there is a growing need for project management approaches that can adjust to shifting market conditions, maximize efficiency, and satisfy project goals. The construction industry adds another layer of complexity to project management with considerations including stakeholder expectations, environmental concerns, and regulatory constraints.

In light of these difficulties, the construction industry is beginning to acknowledge the need for better project management approaches and resources. If businesses want to survive and thrive in today's dynamic business environment, they must modernize their project management methods. Construction organizations may improve project outcomes, increase efficiency, and decrease risks by embracing creative techniques and utilizing technology-driven solutions (Fargnoli et al., 2020). Given the complex nature of the issues that construction companies encounter while trying to complete projects on schedule, within budget, and according to specifications, it is clear that better project management is essential. The industry must embrace innovation, streamline procedures, and provide project teams with the approaches and resources they need to succeed in today's dynamic environment if the difficulties are going to be addressed. New possibilities for growth, sustainability, and future success can be unlocked by the construction sector through a dedication to excellence and

continual improvement. Research has shown that the implementation of technologies like BIM can significantly enhance performance and safety in construction activities (Fargnoli et al., 2020.

2.2 Revolutionizing Construction with BIM

Modern construction has seen a paradigm shift with the advent of BIM, which has altered every step of the process from planning to design to construction to management (Cousins et al., 2017). BIM is essentially a computer model of a building's or infrastructure project's physical and functional attributes. By incorporating intelligent data into three-dimensional (3D) models, BIM, allows stakeholders to collaboratively integrate, visualize, simulate, and analyze different parts of a project, as opposed to only looking at traditional two-dimensional (2D) drawings (Disney, 2024).

Among BIM's many advantages are the ease with which project teams are able to communicate and work together. BIM promotes interdisciplinary collaboration by consolidating project data in a shared digital environment, lessening the likelihood of mistakes, disagreements, and redos (Tam et al., 2018). In order to maximize design decisions and construction processes, stakeholders such as architects, engineers, contractors, and others can work together in real-time. They can access the most recent project data and provide their expertise.

Better exploration and evaluation of design alternatives is another benefit of BIM which helps stakeholders make better-informed decisions throughout a project's lifespan. Better efficiency and sustainability are the results of using BIM software, which uses virtual simulations and analysis tools to find conflicts early on, validate the performance of designs, and optimize building systems. The ability of BIM to improve project visualization and communication is another major benefit. BIM helps stakeholders provide a more thorough explanation of project ideas and designs to clients, regulatory bodies, and the general public by creating realistic 3D models, graphics, and animations. Not only does this increase participation from stakeholders, but it also helps them comprehend and support the project's goals and results. (Hosseini et al., 2016).

Also, by recording information on the building's components, materials, expenses, and timelines, BIM is a great resource for future projects. Stakeholders are able to monitor resource use, discern possible dangers, and follow the project's progress in real-time with this data-driven method of project management. In addition to boosting project efficiency, BIM streamlines workflows by allowing the integration of BIM with other systems like scheduling, cost estimation, and facility management. (Moradi & Sormunen, 2023).

BIM has many different functions and is revolutionizing the way building is done nowadays. Better information modeling (BIM) improves project results by creating a collaborative, data-rich platform for project management, design, construction, and planning. BIM is well-positioned to become an indispensable tool in molding the future of construction practices and standards as the industry wholeheartedly embraces digitization and innovation. (Moradi & Sormunen, 2023; Hosseini et al., 2016).

2.3 Digitalization in the construction industry and the impact of BIM

The digital transformation of the construction industry, epitomized by the adoption of BIM, signifies a fundamental shift in project planning, design, and execution. Beyond 3D modeling, BIM facilitates a collaborative process that creates and manages digital representations of physical and functional characteristics of buildings or infrastructure, enhancing decision-making throughout the project lifecycle (Aghimien et al., 2022).

By integrating various project phases and disciplines into a cohesive digital workflow, BIM improves accuracy and efficiency, which are crucial for modern construction projects (Jensson, 2017). Additionally, digital technologies like BIM address the pressing need to reduce construction waste and enhance sustainability. BIM supports lean construction principles through detailed planning and simulation, minimizing material waste and optimizing resource use (Aghimien et al., 2022).

2.3.1 Key drivers of digitalization in construction

The adoption of BIM allows for a more holistic approach to project management, integrating various phases and disciplines into a cohesive digital workflow. This integration facilitates improved accuracy and efficiency, which are crucial for meeting the demands of modern construction projects (Jensson, 2017). Beyond enhanced project coordination and communication, other drivers of digitalization include the increasing pressure to reduce construction waste and improve sustainability. BIM supports lean construction principles by allowing detailed planning and simulation, which helps minimize material waste and optimize resource use (Aghimien et al., 2022). Moreover, the integration of the Internet of Things (IoT) in construction projects enhances connectivity and data exchange on construction sites. IoT devices, such as sensors and wearables, collect real-time data on various aspects of the project, including equipment performance, environmental conditions, and worker safety, thereby improving overall project coordination (Jensson, 2017).

The integration of BIM is not just a technical challenge but also a strategic one. Companies must rethink their business models to leverage the full potential of BIM. This includes investing in training and development for employees to become proficient in BIM tools and processes. Additionally, firms need to establish new partnerships and alliances to foster a BIM-friendly ecosystem (Aghimien et al., 2022). The concept of digital partnering is gaining traction in the construction industry. Partnering with organizations that have complementary digital capabilities can provide construction firms with a competitive advantage, improved project performance, and risk reduction through shared digital resources. However, the adoption of digital partnering faces challenges such as poor definition of partnering goals, trust issues, and investment costs (Jensson, 2017).

2.3.2 Challenges and opportunities in digital transformation

Adopting BIM and other digital technologies presents several challenges, including high initial implementation costs and the necessity for a cultural shift within organizations. Resistance to change is common, particularly in an industry accustomed to traditional methods. Overcoming

these challenges requires strong leadership and a clear vision of the benefits of digital transformation. Companies that embrace this change can achieve increased market share through differentiation, improved project margins through efficiency gains, and enhanced client satisfaction through better project outcomes (Aghimien et al., 2022).

One of the most significant benefits of BIM is its ability to foresee and mitigate issues before they arise on-site. Detailed visualization and analysis capabilities allow project teams to plan more accurately and execute more effectively. This foresight extends to cost management, where BIM provides detailed cost estimates and tracks expenses in real-time, reducing the likelihood of budget overruns. Moreover, BIM's capacity to simulate various construction scenarios allows for the optimization of methods and sequences, leading to further cost savings and efficiency gains (Aghimien et al., 2022).

2.3.3 Enhanced collaboration and communication

BIM not only enhances collaboration within project teams but also with clients and external stakeholders. Clear visual representations of the project help align the expectations of all involved parties (Aghimien et al., 2022). This collaborative approach facilitates early identification and resolution of design conflicts, resulting in improved project outcomes in terms of cost efficiency, time management, and quality assurance (Jensson, 2017). Real-time updates and modifications ensure that everyone works with the most current information, enhancing the overall quality and coherence of the project (Aghimien et al., 2022).

2.4 Model-Based Construction

Model-based construction refers to the utilization of detailed digital models throughout the entire construction process, from initial design to final execution and facility management These models serve as comprehensive repositories of information, capturing every aspect of the project, including architectural elements, structural components, and MEP systems (Disney et al., 2023). By integrating these models into construction workflows, project teams can achieve higher levels of precision, coordination, and efficiency.

Model-based construction enables real-time collaboration among stakeholders, allowing architects, engineers, contractors, and owners to work from a single source of truth. This approach minimizes discrepancies and reduces the risk of errors and rework, leading to improved project outcomes. Additionally, the use of detailed models facilitates better planning and visualization, helping teams to anticipate and address potential issues before they arise (Disney et al., 2023).

2.5 Total BIM

Total BIM represents a paradigm shift in construction methodology, where BIM is embraced as the primary source of information throughout all project phases. Unlike traditional approaches that rely on disconnected static information sources, Total BIM offers a dynamic, cloud-based solution that streamlines communication, collaboration, and decision-making on construction sites. By eliminating the need for separate 2D drawings and technical documents, Total BIM ensures that all stakeholders have access to a single, up-to-date source of information that serves as the legal and contractual document for the project (Disney et al., 2023).

Total BIM introduces several key features and benefits that enhance the construction process and improve overall project outcomes. One of the fundamental aspects of Total BIM is the ability of site workers to dynamically extract and create construction information on-site. By

leveraging modern BIM-viewer software, construction workers can filter, create, and extract information from the BIM model in real-time, enabling them to work in a dynamic environment rather than relying on static information sources. This shift in work methods empowers site workers to become creators of information, leading to increased efficiency, accuracy, and collaboration on construction sites (Disney et al., 2023).

Moreover, Total BIM serves as a communication and management platform that integrates various information sources, such as on-site photos, BIM data, and short descriptions, to document Requests for Information (RFIs) and streamline decision-making processes. By using mobile devices and cloud-based technology, project teams can access real-time information, track project status, and address issues promptly, reducing handling times and improving overall project visibility (Disney et al., 2023)

2.5.1 Challenges of implementing Total BIM

While Total BIM offers significant advantages in terms of information management and collaboration, its implementation is not without challenges. One of the key considerations in adopting Total BIM is the need for advanced software and hardware that can support large BIM models and ensure interoperability across different platforms. Additionally, standard contracts may need to be modified to recognize BIM as the legally binding construction document, a process that may require regulatory changes in some countries. Furthermore, Total BIM sets new demands on project stakeholders, requiring them to adapt to new work methods and processes that prioritize dynamic information creation and extraction on construction sites. This shift in roles and responsibilities necessitates a reevaluation of traditional construction practices and a commitment to ongoing training and skill development to ensure successful implementation of Total BIM (Disney et al., 2023).

2.6 Power BI

Microsoft Power BI is an advanced suite of business analytics tools designed to extend the functionalities of Excel, enabling users to manipulate, analyze, and visualize diverse data effectively. Launched as an evolution of several Excel add-ons, Power BI integrates data analysis and visualization capabilities into a comprehensive platform that supports informed decision-making through interactive visual representations (Becker & Gould, 2019).

Power BI was developed to address the increasing need for robust data analysis tools that go beyond the traditional spreadsheet functionalities offered by Excel. It consists of several components that work together seamlessly to provide a powerful data analytics solution. Power Query, a core element of Power BI, is integrated into Excel under the name "Get and Transform." This tool allows users to access, clean, and reshape data from a wide variety of sources, making it a versatile option for handling complex data sets. Power Query uses a scripting language known as "M," which enables users to perform data transformations through a graphical user interface or by writing scripts. These transformations can be automated and reused, enhancing efficiency and consistency in data processing (Becker & Gould, 2019).

Power BI also includes Power Pivot and Power View, which were originally Excel add-ons but are now integral parts of the Power BI suite. Power Pivot allows for advanced data modeling and mathematical calculations without the limitations of Excel's grid system. Power View

provides interactive data visualization capabilities, making it easy to create dynamic charts and graphs that help uncover insights and trends in the data. Additionally, Power BI offers a standalone application, Power BI Desktop, which combines data preparation, modeling, and visualization in one environment. This desktop version is complemented by the

Power BI cloud service, enabling users to share and collaborate on reports and dashboards online (Becker & Gould, 2019). The cloud service facilitates seamless collaboration by allowing users to publish reports, create interactive dashboards, and share insights with others within the organization or publicly. For organizations with specific security and data privacy needs, Power BI also offers an on-premises solution through the Power BI Report Server, which allows reports to be shared via an intranet with locally managed permissions (Becker & Gould, 2019).

Power BI provides a comprehensive and flexible solution for data analysis and visualization, bridging the gap between spreadsheets and advanced analytics tools. It empowers users to make data-driven decisions by transforming raw data into actionable insights through intuitive and interactive visualizations (Becker & Gould, 2019).

2.7 The transformative power of digital field reporting in construction

Digital field reporting in the construction industry has emerged as a transformative tool that revolutionizes project management, communication, and data analysis on construction sites. This shift towards digitalization is driven by the industry's increasing need for enhanced efficiency, accuracy, and collaboration to meet the demands of modern construction projects.
Digital field reporting in the construction industry refers to the process of capturing, documenting, and managing project-related information digitally using specialized software, mobile applications, and digital forms (Cusumano et al., 2024). This approach builds upon the integration of automated data acquisition technologies for progress measurement in construction projects as discussed by El-Omari and Moselhi (2011). Cusumano et al. (2024) states that digital field reporting plays a crucial role in streamlining project communication, enhancing data accuracy, and improving overall project efficiency.

2.7.1 Key aspects of Digital Field reporting

Digital field reporting enables construction professionals to capture inspection remarks, production issues, and project data in real-time using mobile devices such as smartphones and tablets (Cusumano et al., 2024). Similarly, El-Omari and Moselhi (2011) highlighted the use of tablet PCs for on-site data collection to streamline project tracking and reporting processes. By digitizing the reporting process, project teams can document observations, track progress, and communicate issues efficiently. Digital field reporting platforms facilitate the organization and management of project-related information, including inspection reports, photos, videos, and annotations. Centralized databases and cloud-based storage systems ensure that project data is accessible, searchable, and secure for all stakeholders. Digital field reporting promotes collaboration among project team members by providing a centralized platform for sharing information, assigning tasks, and tracking project updates. Real-time communication tools enable instant feedback, issue resolution, and decision-making, enhancing project coordination and efficiency (Cusumano et al., 2024).

By digitizing inspection processes and production reporting, construction companies can improve quality control measures, monitor project progress, and identify potential issues proactively. Digital field reporting tools enable real-time tracking of project metrics, performance indicators, and compliance requirements. Digital field reporting often integrates with BIM software and 3D modeling tools to enhance visualization, coordination, and data exchange on construction projects. By linking digital reports to 3D models, project teams can visualize issues in context, analyze spatial relationships, and streamline decision-making processes (Cusumano et al., 2024).

2.7.2 Current benefits of Digital Field Reporting:

According to Cusumano et al., (2024), there are several key benefits associated with digital field reporting in construction projects. These benefits include time savings, cost reductions, increased general quality control, and improved project efficiency. By leveraging mobile phones and tablets, contractors can digitally collect and manage large volumes of production remarks, facilitating data acquisition and analysis. This practice aligns with the use of various automated data acquisition technologies such as RFID and barcoding for efficient data collection in construction projects as explored by El-Omari and Moselhi (2011). The availability of digital inspection data enables better decision-making, enhances project monitoring, and improves overall project quality (Cusumano et al., 2024).

Advancements in technology have played a crucial role in the evolution of digital field reporting within the construction industry. The introduction of specialized production software, mobile applications, and digital inspection forms has streamlined data acquisition processes and enhanced data quality. The integration of artificial intelligence (AI) and machine learning techniques offers opportunities for advanced data analysis, clustering, and keyword extraction, enabling construction companies to derive valuable insights from unstructured data (Cusumano et al., 2024).

Despite the numerous benefits of digital field reporting, the industry faces several challenges in its adoption and implementation. Resistance to change, concerns about data security and integrity, and the lack of standardization in reporting practices pose significant hurdles to the widespread adoption of digital technologies. These challenges are consistent with the issues identified by El-Omari and Moselhi (2011) in the adoption of automated data collection technologies in construction. Inspectors reluctance towards digital reporting, as highlighted by Cusumano et al., (2024), underscores the need for addressing user concerns and ensuring seamless integration of digital tools into existing workflows (Cusumano et al., 2024).

2.8 Evolving quality management in construction

The detailed documentation and tracking capabilities of BIM ensure that projects meet regulatory requirements and quality standards. This capability is particularly valuable in complex projects with stringent regulatory oversight. BIM allows for the easy generation of compliance reports and the ability to quickly address any issues that arise. Quality assurance is also enhanced through BIM's ability to simulate construction processes and detect potential issues before they occur, ensuring that the final build meets all specified standards and client expectations (Jensson, 2017).

Quality management in the construction industry is a critical factor that determines the success and sustainability of projects. It encompasses various aspects such as reliability, durability, and safety of construction outputs, including buildings, infrastructure, and other facilities. Achieving high quality in construction projects is essential not only for meeting the expectations of clients and stakeholders but also for ensuring the safety and longevity of the structures. Effective quality management involves meticulous planning, execution, and continuous monitoring to adhere to predefined standards and specifications. This discussion will delve into the historical challenges of quality in construction, the evolution of quality management practices, and the current state of quality issues in the industry, drawing insights from the provided texts (Ashokkumar.D, 2014)

2.8.1 Current Challenges in Quality Management

Despite advancements in quality management practices, the construction industry still faces several quality challenges that impact project outcomes. Inadequate communication between project stakeholders can lead to misunderstandings, errors, and delays, affecting overall project quality. Additionally, fluctuations in the availability of construction materials and labor can impact project timelines and quality standards. The shortage of skilled workers in the construction industry continues to result in poor workmanship and compromised quality. Moreover, meeting regulatory requirements and building codes is essential for ensuring quality and safety in construction projects, yet it remains a significant challenge for many firms (Abas et al., 2015).

To address these quality issues effectively, construction firms need to adopt proactive quality management strategies that focus on prevention, early detection, and continuous improvement. Defining clear quality objectives and performance metrics is essential to measure project success and identify areas for improvement. Developing standardized processes for quality assurance, including regular inspections, testing, and compliance checks, helps ensure consistent quality throughout the project lifecycle. Furthermore, investing in training programs to enhance the skills and knowledge of construction personnel is crucial for ensuring high-quality workmanship (Abas et al., 2015).

2.8.2 Future Opportunities and Strategies for Improvement

Leveraging digital tools such as BIM, project management software, and quality control apps can streamline quality management processes and enhance collaboration. Technologies like artificial intelligence, Internet of Things (IoT), and robotics enable real-time monitoring, predictive analytics, and automation of quality control processes. For example, integrating advanced technologies into the construction process can significantly improve quality, but it is essential to ensure these technologies are implemented correctly and that workers are trained to use them effectively (Abas et al., 2015).

Modern construction projects must also consider environmental sustainability, which adds complexity to quality management. Incorporating green building practices, energy-efficient designs, and disaster-resistant construction techniques can enhance project quality and longevity. Ensuring that quality management includes sustainability considerations can enhance the overall quality and impact of construction projects (Ashokkumar. D., 2014).

Looking ahead, there are several opportunities for construction firms to further enhance project quality and drive continuous improvement. Embracing emerging technologies can revolutionize quality management practices in construction. These technologies facilitate real-

time monitoring, predictive analytics, and automation of quality control processes. Cultivating a culture of quality within organizations involves promoting accountability, empowering employees to take ownership of quality outcomes, and fostering a mindset of continuous learning and improvement (Abas et al., 2015).

Collaboration with industry peers, academia, research institutions, and technology providers can facilitate knowledge sharing, best practice exchange, and innovation in quality management. Staying abreast of evolving regulations, building codes, and industry standards is essential for ensuring compliance and upholding quality benchmarks in construction projects (Abas et al., 2015).

The construction industry has made significant strides in improving quality management practices over the years. By learning from historical quality issues, embracing technological advancements, and structuring quality management processes, construction firms can elevate the quality of their projects, drive innovation, and achieve sustainable growth in the dynamic construction landscape. Addressing the root causes of quality issues, understanding the impact of poor quality on project outcomes, and implementing effective quality management strategies are key to overcoming quality challenges and driving positive outcomes in construction projects (Abas et al., 2015; Ashokkumar, 2014; Abdul-Rahman, 1997)

2.9 Harnessing data visualization and analytics in construction management

In recent years, the construction industry has increasingly recognized the value of data visualization and analytics in improving project performance and decision-making processes. The immense volume and complexity of data generated during construction projects necessitate advanced tools and techniques to effectively manage and interpret this data. This study explores the principles, benefits, and applications of visualization and data analysis within the construction industry, drawing on two comprehensive studies to provide a detailed understanding of the subject (Korde, 2005; Chiu and Russell, 2011).

2.9.1 The role of visualization in Construction Management

Visualization in construction management involves the use of computer-supported, interactive visual representations of data to amplify cognition and support decision-making processes. Card et al., (1999) define visualization as the act of interpreting in visual terms or putting data into a visible form to enhance understanding and insight. Visualization techniques facilitate the identification and communication of interdependent relationships across various data items, thus improving the ability to interpret data and make informed decisions.

The concept of data visualization has evolved significantly over the decades. Initially, it was used for statistical graphics in the 1960s and 1970s and later developed for information search in the 1980s and 1990s. The advent of visual analytics—a paradigm that uses visual representations and interactions to accelerate insights into complex data—has transformed data analysis in construction management (Chiu and Russell, 2011).

The benefits of data visualization in construction are manifold. Visualization can amplify cognition of quantitative data, improve data accuracy and completeness, reduce comprehension

time, provide rich overviews of project status, and prevent misconceptions due to data inadequacies. Furthermore, the visualization can explain the divergence between planned and actual project outcomes, thus enhancing the quality of construction schedules (Chiu and Russell, 2011)

A data visualization environment in construction management should support both human-based and machine-based analytics. This interactive environment should allow users to access and navigate visual representations of complex data, illustrating salient characteristics of construction conditions, performance, and dependencies. The environment should include features such as pre-coded visual representations, sequences of activities, and associated conditions to facilitate analytic reasoning. Three essential requirements for a construction management (CM) data visualization environment include: an extendable gallery of visual representations, the ability to associate construction conditions with individual activities, and the ability to display sequences of activities and conditions. These requirements ensure that users can effectively analyze and interpret construction data to support decision-making (Chiu and Russell, 2011)

2.9.2 Applications and Case Studies

Several case studies demonstrate the practical applications and benefits of data visualization in construction. For example, a case study on the Advanced Light Rapid Transit Project in Vancouver used a construction data visualization environment to manage time performance during planning, execution, and post-execution phases. This environment helped identify deviations in construction conditions and provided insights into performance issues (Korde, 2005).

Visualization techniques such as scatter plots, treemaps, and 3D models have been used to represent structured construction data, offering additional insights into schedule quality and resource distribution. These techniques facilitate the understanding of work sampling data, progress measurements, and the impact of site conditions on project performance (Chiu and Russell, 2011).

2.9.3 Integration of Visualization Techniques

The integration of advanced interactive tools and visual analytic techniques into construction management functions can significantly enhance project performance. Despite the modest effort expended by the construction academic community, the potential for visualization to support a diverse range of CM functions is immense. Visualization of heterogeneous, multi-source, and time-varying data can provide critical insights into construction management, aiding in the interpretation and analysis of complex datasets (Chiu and Russell, 2011)

2.9.4 Challenges and Future Directions

Implementing visualization techniques in construction management presents several challenges. Different users have varying preferences for visual formats, and some may require expert assistance to interpret visual data. Additionally, the transition from interactive digital formats to static hard copies can result in a loss of interaction benefits. Overcoming these challenges requires the development of user-friendly, interactive visualization environments that cater to diverse user needs and preferences (Chiu and Russell, 2011).

Future work in data visualization for construction should focus on developing causal models to explain project performance, exploring appropriate visualization formats for different data

types, and integrating rich content profiles, filtering, and data aggregation features into visualization systems. These advancements will enhance the usability and effectiveness of visualization tools in construction management (Chiu and Russell, 2011).

3 Methods and Data

This section outlines the comprehensive methodology employed to investigate the integration of StreamBIM data into Power BI, focusing on enhancing project management practices, including inspection protocols within the construction industry. The methodology comprises research design, data collection methods, data analysis techniques, evaluation, and validation strategies to ensure a thorough understanding of the subject matter.

The project involves the construction of residential buildings in Gothenburg. The project presents various challenges typical of large-scale construction, such as coordinating multiple disciplines, managing vast amounts of data, and ensuring quality and compliance through rigorous inspection processes. Common issues encountered in this project include communication between stakeholders and filtering by the issues due to the lack of options for that in StreamBIM.

3.1 Research Design

A case study approach has been chosen to provide an in-depth examination of a real-world project. Case studies are effective for gaining detailed qualitative insights and understanding the complexities of integrating technological tools in practical settings (Yin, 2018). This approach enables the collection of detailed qualitative data, offering a robust analysis of the integration of StreamBIM and Power BI and its impact on project management, including improving inspection protocols.

By focusing on a single project, this methodology allows for a nuanced understanding of the practical applications, benefits, and challenges of technological integration. The applied nature of this approach is designed to generate actionable insights and solutions that can be implemented to improve project management practices.

3.2 Data Collection

Two types of data have been collected: primary and secondary data.

Primary data:
Semi-structured interviews were conducted with key stakeholders, including the project manager and supervisor involved in the project. This method allows for flexibility in exploring various aspects of the integration process while ensuring that key topics are thoroughly covered, making it particularly useful for gaining deep insights into participants experiences and perspectives (Kallio et al, 2016). Through these interviews, project managers shared their views on the impact of integration on project management, decision-making processes, and efficiency, especially in the context of inspections. Supervisors provided technical insights into the integration process, data handling, and the specific challenges they encountered during inspections.

The choice of semi-structured interviews is based on their ability to provide detailed and rich qualitative data while allowing the interviewer to probe deeper into specific areas of interest that emerge during the conversation. Semi-structured interviews were conducted with key stakeholders, including the project manager and supervisors involved in the project. These interviews explored various aspects of the integration process and focused on understanding its impact on project management practices, decision-making processes, and efficiency, especially in the context of inspections. Interviewees provided insights into typical on-site issues, the

frequency and types of inspection problems encountered, and the effectiveness of the digital tools used.

Secondary Data:
The secondary data collected was project documentation provided by the company, including construction plans, progress reports, and inspection reports. This method is effective for understanding the project context and current management practices (Bowen, 2009).

The construction project is guided by detailed blueprints and specifications that outline the design and scope, ensuring every aspect is carefully planned. Progress is regularly documented through periodic reports generated by StreamBIM, providing updates on project status, milestones achieved, and any issues encountered.

This data was collected because it provides comprehensive background information and context for the project. This method allows for triangulating data collected through other means, ensuring a more robust understanding of the project's processes and outcomes.

The workflow data from StreamBIM was used in this study during the integration of StreamBIM and Power BI. This dataset includes both qualitative and quantitative workflow data. Although this data was created to manage the construction project and was not explicitly collected for this research, it is classified as secondary data for the purposes of this study.

The secondary data collected included project documentation, such as construction plans, progress reports, and inspection reports. This documentation included detailed blueprints, specifications, periodic progress updates from StreamBIM, and thorough inspection reports capturing findings from both pre-inspection and final inspections. The data was collected to provide comprehensive background information and context for the project, allowing for triangulation of data collected through interviews.

Integration of Stream BIM with Power BI: As we aimed to integrate data from Stream BIM into Power BI, we discovered that only a few datasets had the capability for direct integration. Among these, the dataset containing the project workflow stood out due to its comprehensive nature and relevance to our objectives. This dataset encompassed critical information related to ongoing issues in the project, including their status (open, closed, or done), the dates when these issues were opened and closed, the individuals to whom the issues were assigned, and the priority level of each issue.

Given the scale of the project, which involves two buildings with multiple floors, this workflow dataset provided a substantial volume of data. The richness of this dataset, combined with its direct compatibility with Power BI, made it an ideal choice for our analysis. By selecting this dataset, we were able to leverage its detailed insights into project progress and issue management, allowing for more effective tracking and visualization of key project metrics within Power BI.

3.3 Data Analysis

For the analysis of qualitative data, recordings from online meetings were utilized, and a transcription program was employed to accurately capture the important points discussed. This thorough process, as outlined by Green et al (2007), involves several key steps to ensure reliability and depth.

First, all online meetings and interviews were recorded with the consent of the participants. These recordings were then transcribed using reliable transcription software, ensuring that the data was accurately documented for further analysis. Next, the transcribed data was meticulously reviewed to identify key themes and significant points. This involved multiple readings of the transcripts to ensure a deep understanding of the content and to capture all relevant information related to the integration of StreamBIM and Power BI.

From these reviewed transcripts, key insights were extracted, focusing on the benefits and challenges of the integration, the impact on pre-inspection and final inspection protocols, and overall improvements in project management practices. These insights were categorized based on their relevance to the research objectives. Finally, the extracted insights were synthesized to form a coherent narrative that addresses the research questions. This involved linking the findings from the interviews and meetings to the broader context of the research, highlighting how the integration of StreamBIM and Power BI enhances decision-making processes, communication, and project efficiency.

This structured approach to data analysis ensures that the findings are thorough and reliable, providing a detailed understanding of the integration process and its outcomes. By systematically reviewing and synthesizing the data, the research presents well-founded conclusions grounded in the collected evidence.

3.4 Data integration process

We started by requesting StreamBIM support to enable the Power BI export feature for our project. Once this feature was activated, we navigated to the relevant user screen in StreamBIM, such as Workflow data inside Capture or checklists, and used the export option available there. StreamBIM then generated a query script for Power BI, which I copied to my clipboard.

In Power BI Desktop, we created a "Blank Query" and opened the "Advanced Editor" to paste the StreamBIM script. After loading the data, we proceeded to create the desired visualizations and set up a scheduled refresh to keep the data updated. After loading the data into Power BI, we refined and shaped it to fit our visualization needs. Using Power BI’s modeling tools, we connected different data tables and set up relationships to ensure a cohesive data model. Then, we built various visuals, including charts and tables, to effectively represent the StreamBIM data. we configured the visuals to be dynamic, allowing stakeholders to interact with the data in real time. Finally, we set up a scheduled refresh within Power BI to ensure the data remains up-to-date automatically.

After setting up the scheduled refresh in Power BI, we ensured that the data connections were stable by testing the refresh process. This involved checking that the data was pulling in accurately from StreamBIM and that all relationships and transformations within Power BI remained intact. With everything functioning as expected, we finalized the Power BI report, organizing the dashboards and visuals to be user-friendly and insightful. We can then share the report with the relevant stakeholders, giving them the ability to interact with and analyze the

up-to-date project data directly from Power BI. This seamless integration allowed for real-time data insights, improving project management and decision-making processes.

3.5 Ethical Considerations

Ethical considerations are paramount in this research. All participants will be informed about the purpose of the study and their rights, including confidentiality and the right to withdraw at any time. Consent will be obtained from all participants before data collection. Data will be stored securely and anonymized to protect participants identities (Babbie et al, 2016).

Ensuring ethical standards protects participants and enhances the credibility and integrity of the research.

4 Results

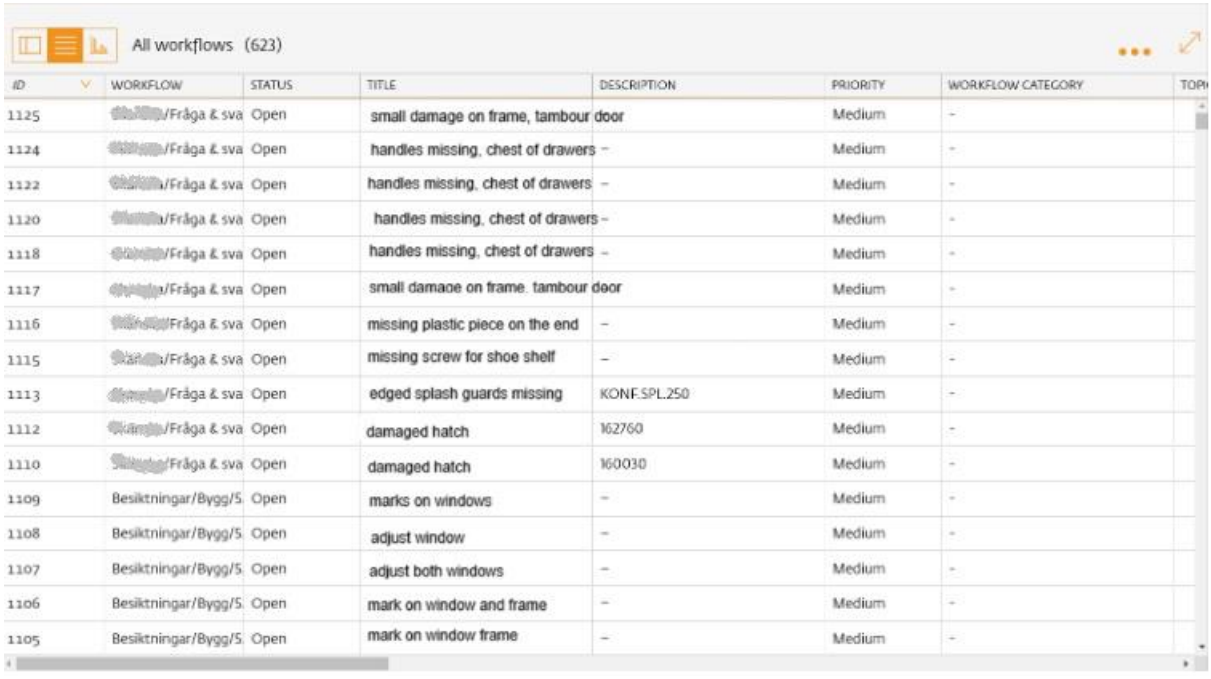
4.1 Integration of Real-time Data from StreamBIM to Power BI

The integration of real-time data from StreamBIM to Power BI has been a focal point of our study, aiming to address the challenges faced in data management and visualization within construction projects. StreamBIM features a built-in capability to connect its data directly to Power BI, facilitating a seamless integration process that enhances data handling and visualization. This integration has been particularly beneficial in transforming how data is filtered, analyzed, and presented, significantly improving the efficiency and accuracy of project management tasks.

4.2 Results for integrating StreamBIM to Power BI

4.2.1 Visual Representation of Data for Integrating StreamBIM and Power BI

Figures 1 and 2 illustrate how data from StreamBIM are displayed. These figures show the initial layout of data within StreamBIM, highlighting the structured format used to organize project documentation. Each discipline and floor are assigned specific files and folders, with detailed tickets created for each issue. This organization is essential for maintaining a comprehensive record of all project activities and ensuring that any issues are tracked and resolved efficiently. In Figure 2 the left side of the image shows how the issues are structured in the project. In figure 3 we see the number of topics that are

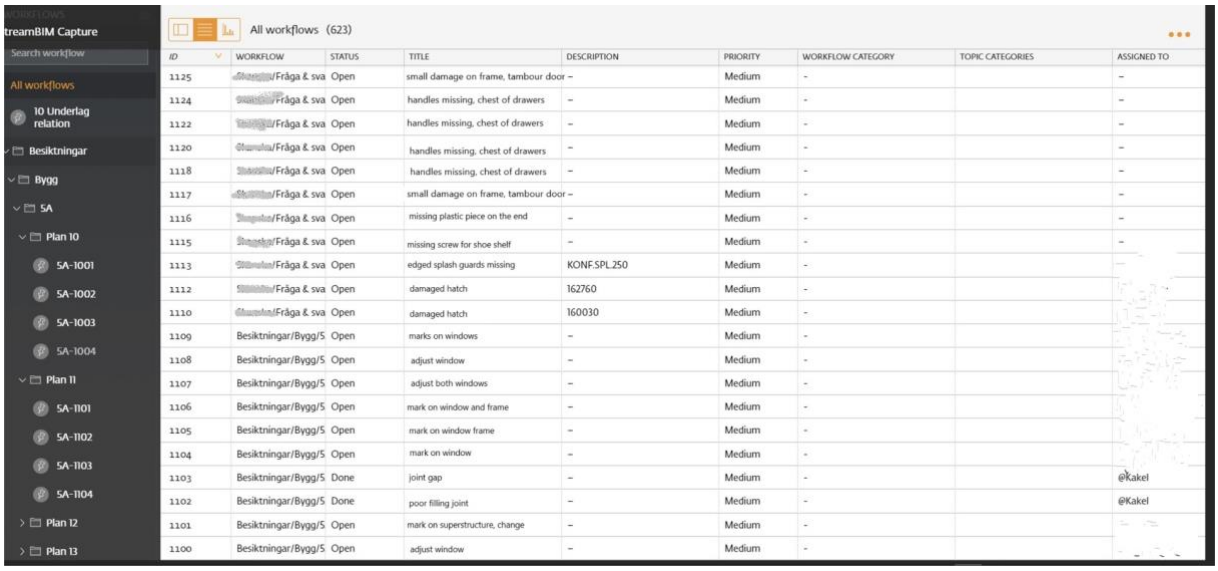


ID	WORKFLOW	STATUS	TITLE	DESCRIPTION	PRIORITY	WORKFLOW CATEGORY	TOPI
1125	/Fråga & sva	Open	small damage on frame, tambour door		Medium	-	
1124	/Fråga & sva	Open	handles missing, chest of drawers	-	Medium	-	
1122	/Fråga & sva	Open	handles missing, chest of drawers	-	Medium	-	
1120	/Fråga & sva	Open	handles missing, chest of drawers	-	Medium	-	
1118	/Fråga & sva	Open	handles missing, chest of drawers	-	Medium	-	
1117	/Fråga & sva	Open	small damage on frame, tambour door		Medium	-	
1116	/Fråga & sva	Open	missing plastic piece on the end	-	Medium	-	
1115	/Fråga & sva	Open	missing screw for shoe shelf	-	Medium	-	
1113	/Fråga & sva	Open	edged splash guards missing	KONE.SPL.250	Medium	-	
1112	/Fråga & sva	Open	damaged hatch	162760	Medium	-	
1110	/Fråga & sva	Open	damaged hatch	160030	Medium	-	
1109	Besiktningar/Bygg/S	Open	marks on windows	-	Medium	-	
1108	Besiktningar/Bygg/S	Open	adjust window	-	Medium	-	
1107	Besiktningar/Bygg/S	Open	adjust both windows	-	Medium	-	
1106	Besiktningar/Bygg/S	Open	mark on window and frame	-	Medium	-	
1105	Besiktningar/Bygg/S	Open	mark on window frame	-	Medium	-	

Figure 1. Workflow layout in StreamBIM

However, the inherent limitations in visualizing this data within StreamBIM necessitate the use of more advanced tools like Power BI. With the integration process, data from StreamBIM can be exported and visually represented in Power BI, offering enhanced flexibility and customization. Power BI's capabilities enable the creation of dashboards that present data in a

visually appealing and informative manner. For instance, issues can be categorized and displayed using various chart types, providing a clearer and more comprehensive view of the project's status.



ID	WORKFLOW	STATUS	TITLE	DESCRIPTION	PRIORITY	WORKFLOW CATEGORY	TOPIC CATEGORIES	ASSIGNED TO
1125	[redacted]/Fråga & sva	Open	small damage on frame, tambour door	–	Medium	-		–
1124	[redacted]/Fråga & sva	Open	handles missing, chest of drawers	–	Medium	-		–
1122	[redacted]/Fråga & sva	Open	handles missing, chest of drawers	–	Medium	-		–
1120	[redacted]/Fråga & sva	Open	handles missing, chest of drawers	–	Medium	-		–
1118	[redacted]/Fråga & sva	Open	handles missing, chest of drawers	–	Medium	-		–
1117	[redacted]/Fråga & sva	Open	small damage on frame, tambour door	–	Medium	-		–
1116	[redacted]/Fråga & sva	Open	missing plastic piece on the end	–	Medium	-		–
1115	[redacted]/Fråga & sva	Open	missing screw for shoe shelf	–	Medium	-		–
1113	[redacted]/Fråga & sva	Open	edged splash guards missing	KONF.SPL.250	Medium	-		
1112	[redacted]/Fråga & sva	Open	damaged hatch	162760	Medium	-		
1110	[redacted]/Fråga & sva	Open	damaged hatch	160030	Medium	-		
1109	Besiktningar/Bygg/5	Open	marks on windows	–	Medium	-		
1108	Besiktningar/Bygg/5	Open	adjust window	–	Medium	-		
1107	Besiktningar/Bygg/5	Open	adjust both windows	–	Medium	-		
1106	Besiktningar/Bygg/5	Open	mark on window and frame	–	Medium	-		
1105	Besiktningar/Bygg/5	Open	mark on window frame	–	Medium	-		
1104	Besiktningar/Bygg/5	Open	mark on window	–	Medium	-		
1103	Besiktningar/Bygg/5	Done	joint gap	–	Medium	-		@Kakel
1102	Besiktningar/Bygg/5	Done	poor filling joint	–	Medium	-		@Kakel
1101	Besiktningar/Bygg/5	Open	mark on superstructure, change	–	Medium	-		
1100	Besiktningar/Bygg/5	Open	adjust window	–	Medium	-		

Figure 2. Workflow layout in StreamBIM

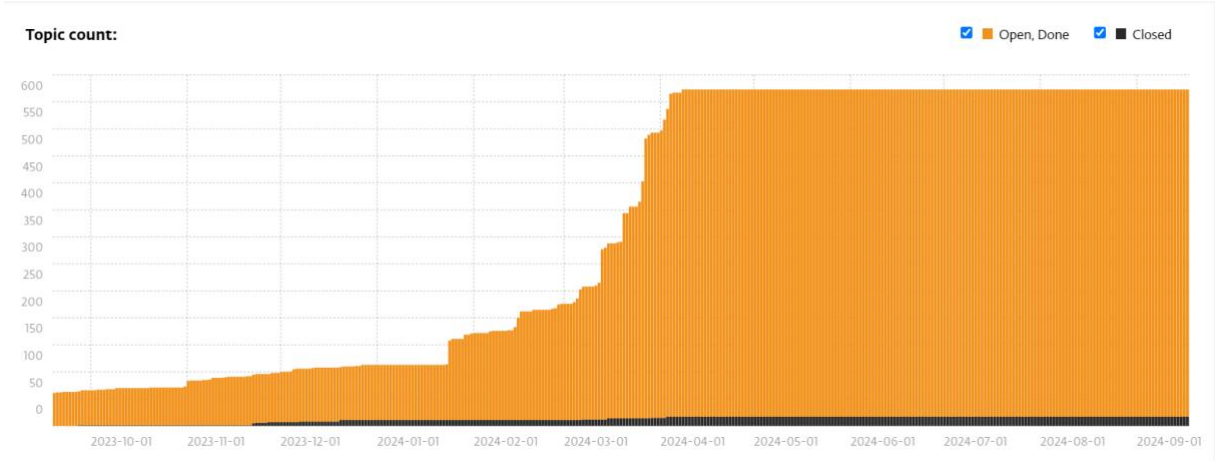


Figure 3. Topic count graph in StreamBIM

In Power BI, data can be organized into dashboards according to the specific requirements of the site engineer or project manager. This customization includes arranging information in a way that highlights key metrics and trends, making it easier to monitor progress and identify potential issues. For example, a dashboard might include a series of charts showing the number of issues identified, the status of each issue (open, done, or closed), and the responsible party for resolving each issue. In Figure 3 above, you can see the topic count graph in StreamBIM, which illustrates how data visualization tools can be used to track and manage issues efficiently within the platform.

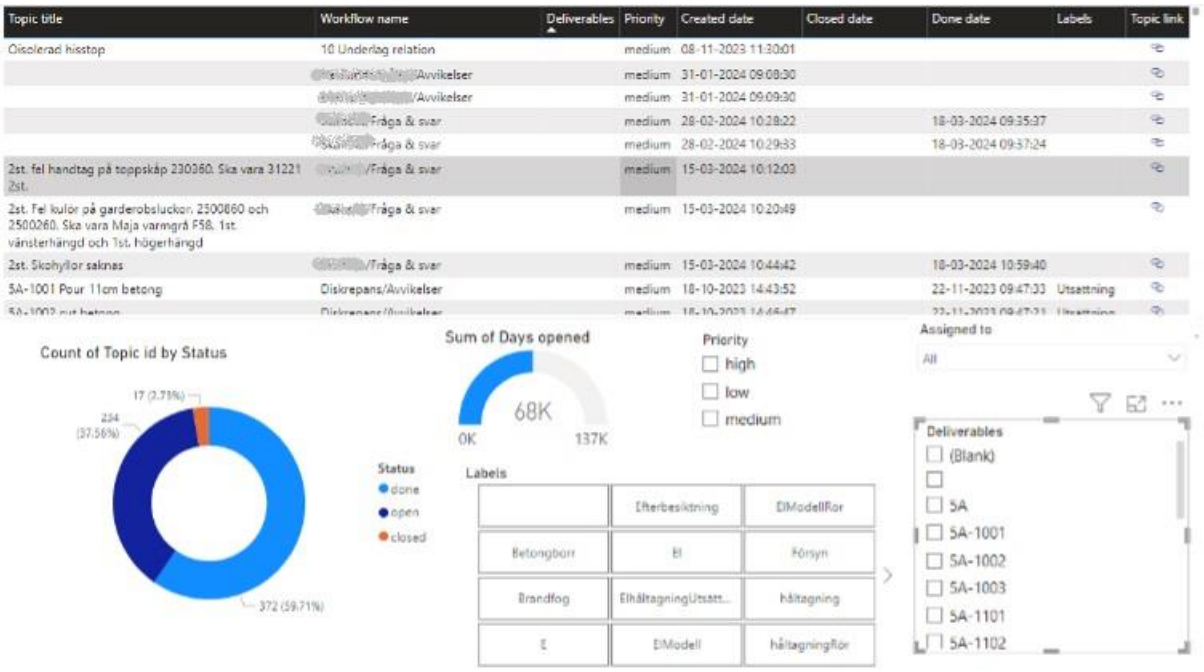


Figure 4. Data from StreamBIM in Power BI

4.2.2 Customization and Filtering Capabilities

In Figure 1, a column named "Title" is populated with issues identified at the construction site. Site supervisors require the ability to filter these issues based on different criteria, such as apartment units and types of inspections. This need for specific filtering capabilities is effectively met in Power BI, as demonstrated in Figure 4, where the same data from StreamBIM is arranged with enhanced visual representation, including a donut chart.

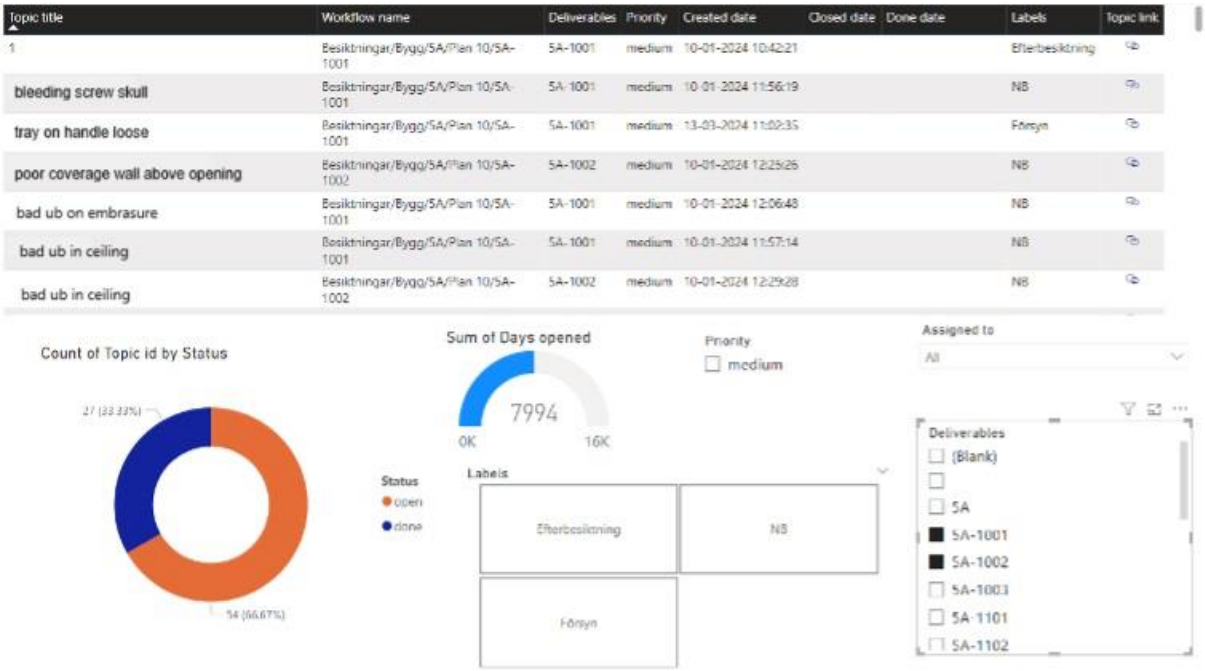


Figure 5. Data from StreamBIM in Power BI with filter in use

Power BI's Slicer tool is particularly valuable, allowing site supervisors to filter information precisely according to their needs. For instance, Figure 5 displays a dashboard that isolates issues related exclusively to two apartment numbers. The Slicer tool enables the filtering of multiple datasets simultaneously. Also, a site manager might need a detailed graph to monitor the project's progress throughout its life cycle. This can be effectively achieved using Power BI. For example, Figure 6 displays a real-time graph that illustrates the project's progress to date.

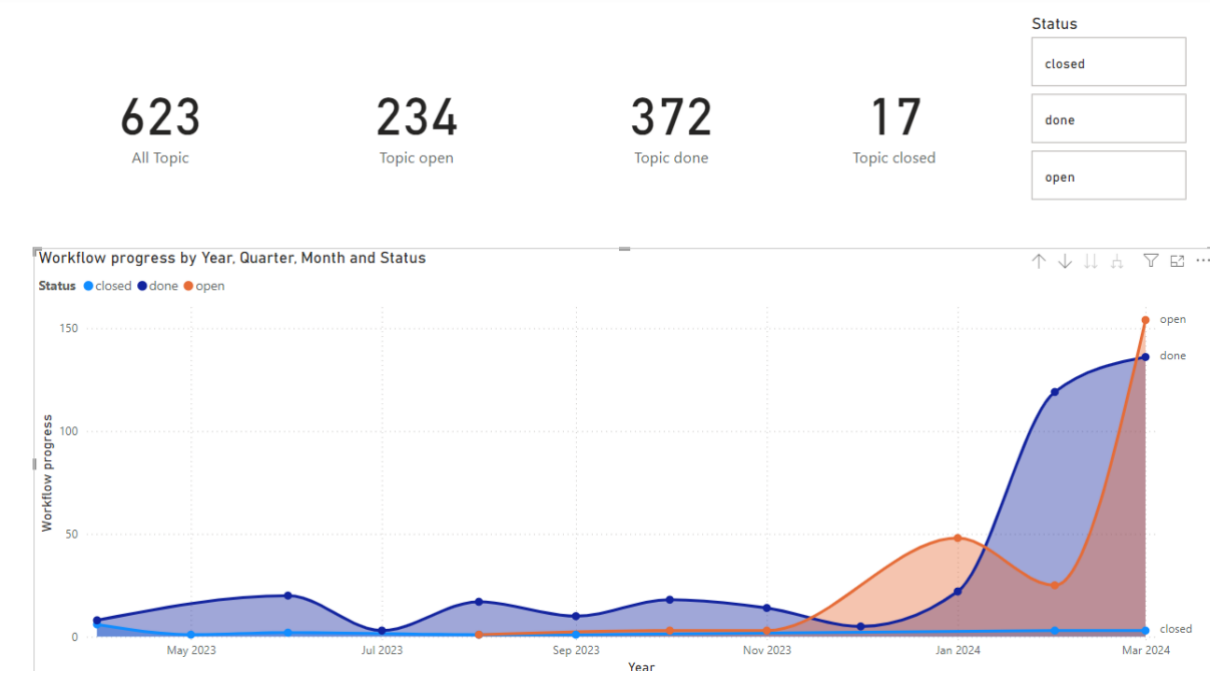


Figure 6. Workflow progress Graph in Power BI

Figure 7. Floor-wise Layout and Apartment Distribution of a Building with Individual Floor and Apartment Slicers

Figure 7 provides a comprehensive visualization of a Building, where each panel represents a distinct floor within the building. The data contained within these panels is tailored to the specific floor being represented. For instance, the second panel from the bottom corresponds to "Plan 10," the second floor. Within this panel, smaller boxes are visible, each marked with a number representing an apartment on that floor. Notably, some panels do not contain these smaller apartment-specific boxes, which indicates that detailed data for individual apartments on those floors is not currently available. This lack of information is reflective of the data constraints within StreamBIM, as Power BI only displays the information that has been uploaded to and is available in StreamBIM.

The design of the dashboard includes multiple slicers and filters that are customized to operate independently from one another. Each panel includes a small black box, functioning as a slicer specific to that floor. These floor-level slicers are carefully configured to ensure that when they are activated, they only filter the data within their respective panels, without impacting the information shown in other panels. This separation of functionality is crucial for maintaining the integrity of the data display across different floors.

Additionally, the smaller boxes within each panel, which contain apartment numbers, also function as slicers. These apartment-level slicers allow for a more granular analysis by filtering the information down to individual units. For instance, if a user wants to view the data related to a specific apartment, they can activate the slicer corresponding to that apartment, and the information will be filtered accordingly within the panel for that floor.

Figure 8. Filtered View of one Apartment within a Building, Isolated by Floor-specific Slicer

Figure 8 illustrates this feature in action, focusing on the slicer for one particular apartment. To know which slicer is in action it can be identified if the box is black in color. In this figure, the slicer is activated, and as a result, the data within the Plan 10 panel is filtered to display information specific to one apartment that has been turned in color. Importantly, this filtering is restricted to the Plan 10 panel, ensuring that the data for other floors and apartments remains

unchanged. This targeted filtering capability enhances the user's ability to conduct detailed examinations of specific units within the building, allowing for a more precise and focused analysis.

This level of control over the data display, through independent slicers for both floors and individual apartments, facilitates a clear and organized approach to data analysis within the building. By allowing users to isolate and examine specific sections and units, the dashboard provides a powerful tool for understanding the distribution and status of information across different parts of Building.

4.3 Results for Inspections

4.3.1 Results from Interviews

The interviews conducted provided valuable insights into the inspection practices within the construction industry. We selected two experienced professionals who were actively involved in a major project, ensuring a broad range of perspectives. Both interviews were conducted digitally, each lasting approximately 60 minutes. This section presents the findings derived exclusively from these interviews.

The respondents emphasized the importance of a structured approach to inspection preparation, particularly through the use of StreamBIM. The first interviewee highlighted, "Each floor has a dedicated folder for each apartment, and inspection points are meticulously documented within these folders." This methodical approach ensures that all necessary documentation is easily accessible, facilitating a more efficient inspection process.

Inspections are typically divided into three main stages:

- **Self-inspection:** Conducted solely by the team without any external inspectors. This initial inspection allows the team to identify and rectify any issues early, ensuring that the work meets internal standards before undergoing external evaluation.
- **Official Inspection:** An external inspector is brought in to conduct a comprehensive review, focusing on compliance with industry standards and regulations.
- **Final Inspection:** This final stage serves as the last checkpoint before sign-off, ensuring that all previously identified issues have been resolved and that the work meets the required standards.

Both respondents detailed the process of creating inspection points within StreamBIM, where issues are logged as detailed tickets, specifying the type of problem, responsible party, and status (e.g., open, finished, or closed). The second interviewee elaborated, "We conduct self-controls through StreamBIM, recording each step digitally to ensure compliance and accuracy." Inspectors also visually mark issues on blueprints within the platform, allowing for efficient management and resolution.

4.3.2 Challenges with StreamBIM according to respondents

Despite the benefits of StreamBIM, both interviewees identified significant challenges with its use. The first interviewee pointed out that generating PDF reports within StreamBIM can

be slow, often forcing the team to export data to Excel. "Generating reports in StreamBIM is slow, leading us to export data to Excel, which loses some visual benefits," they remarked. While Excel is practical, it lacks the visual appeal of PDF reports, which are often more effective for communicating findings to stakeholders.

Another challenge highlighted was the separation of workflows for different disciplines, which sometimes frustrates inspectors who manage multiple areas, such as pipes and ventilation. The second interviewee mentioned, "The electrician and plumbing models are not as detailed, causing issues in filtering and managing inspections accurately."

Both respondents noted a preference for using 2D views over 3D models when marking and navigating inspection points. The first interviewee explained, "We use 2D drawings more than 3D models because they offer a clearer overview and are more familiar to us." This preference is mainly due to habit and the perceived ease of use of the 2D system, although they acknowledged that 3D views could provide more detailed insights if utilized effectively.

4.3.3 Data Collection During Inspections

During inspections, various types of data are collected, including issues related to construction, electrical work, and plumbing. Each issue is marked on the StreamBIM, and detailed notes are added. For example, a scratch on a window frame would be documented with a description, a responsible party assigned, and a status update as the issue progresses.

Despite the system's capabilities, respondents noted that some traditional methods, such as manual note-taking and photography, are still in use due to habit and certain limitations of digital tools. Manual note-taking can be quicker and more flexible in some situations, while photographs provide a visual record that can be easier to interpret than written descriptions.

The process of collecting and reporting data can be further complicated by the need to generate comprehensive reports that summarize all inspection findings.

4.3.4 Enhanced Preparation and Planning

Enhanced preparation and planning involve the integration of 3D BIM models to visualize inspection points and critical areas, enabling a comprehensive understanding of potential issues before they occur. By incorporating these models during the planning stage, inspectors can rehearse tasks in a digital environment, which ensures they are well-prepared and can anticipate challenges before arriving on-site. This proactive approach not only improves efficiency but also minimizes the risk of overlooking critical inspection points. Additionally, establishing a centralized inspection preparation unit can standardize the preparation process across various projects and disciplines. This unit would be responsible for creating consistent checklists and detailed instructions, allowing site supervisors to dedicate more time to the actual inspection process rather than administrative tasks.

4.3.5 Standardization and Automation

Standardization and automation are promoted through the development of standardized templates for common inspection issues and clear protocols for data entry and reporting. This approach ensures all inspections are conducted uniformly, improving the consistency and reliability of the data collected. Furthermore, automating routine tasks such as report generation, data synchronization between StreamBIM and Power BI, and regular updates of

inspection records saves time, reduces the risk of human error, and ensures all stakeholders have access to the latest information.

4.3.6 Training and Familiarization

Training and familiarization are critical to the successful implementation of these improvements. Developing comprehensive training programs for inspectors and supervisors to familiarize them with new digital tools and procedures is essential. These programs should cover the use of 3D BIM models, tablet applications, and data visualization tools like Power BI, ensuring that all users are competent and comfortable with the new systems. Additionally, establishing feedback mechanisms allows inspectors and supervisors to provide continuous input on the inspection process and tools used. This feedback is invaluable for refining and improving the system, ensuring it meets the evolving needs of the project and its stakeholders, fostering a culture of continuous improvement.

5 Discussion

Historically, the construction industry has been slow to adopt new technologies, often relying on manual processes and paper-based documentation. The shift towards digital tools like StreamBIM and Power BI offers the potential for enhanced project management practices. For instance, Aghimien et al. (2022) discuss how BIM improves collaboration and communication among project stakeholders by providing a clear, visual representation of the project, which helps align expectations and identify design conflicts early. This study builds on these findings by demonstrating how integrating StreamBIM data with Power BI can further enhance these capabilities through advanced data visualization and filtering.

The challenges identified with the use of StreamBIM—such as slow PDF report generation, fragmented workflows across different disciplines, and a preference for 2D views—underscore a broader issue within the construction industry: the tendency to adapt traditional methods to new digital tools without fully embracing the potential these tools offer.

Despite the introduction of advanced software like StreamBIM, which is designed to enhance project management through features like real-time data integration and 3D visualization, many users continue to rely on older practices. For instance, the preference for exporting data to Excel for report generation highlights a reliance on familiar, albeit less efficient, methods. This approach bypasses some of the visual advantages that StreamBIM's PDF reports could provide, reflecting a comfort with traditional tools like Excel over newer, potentially more effective options.

The separation of workflows between disciplines such as electrical and plumbing work is another example. This issue suggests that, rather than fully integrating the capabilities of StreamBIM to provide a unified view of the project, users are maintaining siloed workflows that mimic the fragmented approaches used in pre-digital project management. This lack of integration not only leads to inefficiencies but also hinders the comprehensive understanding of the project's overall status, which is one of the primary benefits digital tools are meant to provide.

Moreover, the strong preference for 2D views over 3D models for marking and navigating inspection points further demonstrates this pattern of adapting old methods to new tools without fully leveraging the advantages that digital innovation offers. While 2D drawings are more familiar and thus easier to use for many, they limit the depth of analysis that 3D models can provide. The reluctance to fully adopt 3D models indicates a hesitation to move beyond traditional practices, even when more advanced and effective options are available.

In essence, the respondents' reliance on familiar, traditional methods within a new digital framework suggests that while the tools have evolved, the working methods have not fully adapted to leverage these advancements. This results in suboptimal use of digital tools, where the full potential of BIM and data visualization technologies is not fully realized.

The study found that this method of working, although adapted to new software, still reflects old practices. This highlights a critical area for improvement: the need for cultural and procedural shifts within the industry to fully embrace and exploit the capabilities of digital tools like StreamBIM. Without such a shift, the industry risks continuing to work within the constraints of outdated methods, even as it adopts new technologies.

The integration's most notable contribution it´s the improved data management and visualization capabilities. Previously, StreamBIM was limited by its inherent data visualization tools, which were adequate for basic project management but fell short in complex, multi-disciplinary construction environments. By incorporating Power BI, project managers could transcend these limitations. They could now filter, customize, and visualize data in ways that were previously impossible, tailoring dashboards to meet the specific needs of different stakeholders, from site engineers to upper management.

This enhanced ability to visualize complex datasets allowed for better tracking of project progress, identification of potential bottlenecks, and more informed decision-making. For instance, the study showed that site supervisors could utilize Power BI's advanced filtering tools, such as the Slicer tool as in figure 4 & 6, to isolate specific issues by apartment units or inspection types. This level of customization could facilitate more targeted inspections, ensuring that critical issues were addressed promptly and efficiently.

The results indicate that the integration offers several key benefits, including improved data management, enhanced customization, and the ability to create complex queries that combine multiple criteria for highly specific data views. This is particularly useful in large projects where data is collected from various sources and needs to be analyzed in different contexts. For example, site supervisors in our study were able to create queries that filter data based on specific parameters and display the results in a clear, visual format. This customization capability significantly improves data management and reporting, aligning with the findings of Becker and Gould (2019) who highlighted the advantages of extending Excel capabilities with Power BI for diverse data manipulation and visualization.

By exporting data from StreamBIM to Power BI, users in our study arranged information on customized dashboards that catered to the specific needs of site engineers and project managers. Enhanced visualization capabilities in Power BI, such as pie charts, donut charts, and line charts, allowed for better understanding and communication of complex datasets. This finding is consistent with the work of Chiu and Russell (2011), who emphasized the importance of data visualization in construction management for interpreting and analyzing complex datasets.

The enhanced reporting capabilities of Power BI allow for the creation of detailed, interactive reports that can be shared with stakeholders. These reports can include various data visualizations, making it easier to communicate complex information. For example, a report might include a series of charts showing the distribution of issues by type, the status of each issue, and the progress of resolving these issues over time. This level of detail and interactivity is not possible within StreamBIM alone, highlighting the added value of integrating the two tools.

Additionally, our results showed that these visualizations were particularly effective in tracking inspection points and progress, providing a clear, real-time view of project status. To improve the inspection process, we suggested integrating more automated and user-friendly features into StreamBIM. This includes prefilled templates for common issues, which could save time and reduce the risk of errors when documenting inspection points. Better integration of 3D views could also enhance the detail and accuracy of inspections, providing a more comprehensive view of the project. Faster report generation capabilities were also recommended, as this would make it easier to produce and share detailed reports without the need to export data to Excel.

Additionally, merging workflows for closely related disciplines could streamline the process and reduce frustration for inspectors. By integrating workflows for related areas such as plumbing and electrical work, inspectors could manage their tasks more efficiently and get a better overall view of the project's progress. The customization offered by Power BI extends beyond simple filtering. Users can create complex queries that combine multiple criteria, allowing for highly specific data views. This is particularly useful in large projects where data is collected from various sources and needs to be analyzed in different contexts. A site manager might need a detailed graph to monitor the project's progress throughout its life cycle. This can be effectively achieved using Power BI. For example in figure 5 that displays a real-time graph that illustrates the project's progress to date.

The integration of digital tools like StreamBIM in construction projects represents a significant advancement in data management and reporting practices. However, from the interviews conducted, it was highlighted that while tools like BIM 360 and StreamBIM have facilitated the creation and storage of digital data in centralized environments, there remains a tendency to utilize these tools in a manner similar to traditional methods. This approach often limits the potential benefits that such digital tools can offer. The tools create digital data and store it in centralized environments, where interaction with the software itself is direct. However, it was found that this method still reflects old ways of working, simply adapted to new software.

The current on-site inspection practices in the construction industry involve a mix of digital tools and traditional methods. While systems like StreamBIM offer significant advantages, there are areas for improvement that could enhance efficiency and data management. The integration of more automated features, better use of 3D views, and improved report generation capabilities could help streamline the inspection process and ensure that all issues are addressed in a timely and effective manner. The use of digital tools could be significantly enhanced by adopting a more model-based approach to construction and fully leveraging BIM capabilities. Incorporating object tagging and other advanced features could greatly improve the efficiency and effectiveness of reporting and visualization processes. This approach would facilitate the production of comprehensive reports and visualizations that are more useful for clients and project stakeholders both during and after the project lifecycle.

Despite the shift to digital documentation, many practices remain similar to traditional methods, reducing the efficiency gains that could be achieved with a more comprehensive digital transformation. For example, a donut chart can show the distribution of issues across different apartments, enabling site supervisors to prioritize inspections and address critical problems first. This level of detail and clarity in data presentation is not possible within StreamBIM alone, highlighting the added value of integrating these tools. Enhanced visualization makes data more accessible and understandable, facilitating better decision-making and project outcomes.

The integration process also revealed several challenges. One challenge is the time required to set up and maintain the data integration between StreamBIM and Power BI. While Power BI offers advanced data visualization tools, the initial setup can be time-consuming, and maintaining the integration requires ongoing effort.

Future improvements in the integration of StreamBIM and Power BI could include developing automated templates for common issues in StreamBIM. These templates could streamline the data entry process and reduce the time required to document issues, making it easier for users to manage and analyze data. Another improvement could be better integration of 3D views in Power BI. Currently, most users prefer 2D views due to their familiarity and ease of use, but

3D views can provide more detailed insights and a better understanding of spatial relationships. Integrating 3D views into Power BI could enhance data visualization and provide a more comprehensive view of construction projects, leading to better project management and decision-making.

Based on the findings, several recommendations can be made for practitioners looking to integrate StreamBIM with Power BI. First, it is essential to plan the integration process carefully, considering the specific needs and requirements of the project. This includes identifying key data points and visualization needs to ensure the integration meets the project's goals. Second, practitioners should invest time in training and familiarizing themselves with Power BI's capabilities to fully leverage its potential. Comprehensive training programs can help users understand how to use Power BI effectively, enhancing their ability to manage and analyze data. Finally, ongoing maintenance and data cleaning are crucial to ensure the integration remains effective and the data is accurate. Regular updates and checks can help maintain data integrity and ensure the tools continue to provide valuable insights.

In the long term, these advancements could lead to higher standards of quality control and ultimately, better project outcomes. The integration of digital tools like StreamBIM and Power BI is not just a technological upgrade but a strategic shift towards more effective and sustainable construction practices. As the industry continues to evolve, the lessons learned from this study will likely inform the development of new tools and methodologies that further enhance the efficiency, accuracy, and sustainability of construction projects.

The integration of StreamBIM with Power BI offers significant advantages in terms of data visualization, filtering, and reporting. While there are challenges to address, the benefits far outweigh the drawbacks, making this integration a valuable tool for managing construction projects more efficiently and effectively. The ability to customize data views, use advanced visual tools, and create detailed reports enhances decision-making and improves project outcomes. This integration ultimately leads to better-managed construction projects, highlighting the importance of adopting and fully utilizing digital tools in the construction industry.

6 Conclusion

Based on the research and analysis conducted in this thesis, the integration of StreamBIM with Power BI has demonstrated significant potential to enhance project management and inspection processes in construction projects. This study, centered on a case study of the project in Gothenburg, reveals several key findings and recommendations for industry professionals.

The integration of StreamBIM with Power BI facilitates more efficient data management and advanced visualization capabilities. This integration enables project managers to filter, customize, and visually represent data through interactive dashboards, enhancing the ability to monitor project progress, identify issues, and make informed decisions. These visual tools help in better understanding and communication of complex data sets, thereby improving project outcomes. The use of integrated digital tools significantly improves inspection preparation, execution, and reporting. The ability to plan and visualize inspection points using 3D BIM models ensures that inspections are thorough and efficient. Automated features and standardized templates for common issues streamline the inspection process, reducing the time required and minimizing human errors.

The integration promotes better communication and collaboration among project stakeholders. By providing real-time updates and centralized data access, all stakeholders are kept informed and engaged, leading to more coordinated efforts and improved project delivery. This collaborative approach ensures that issues are addressed promptly, and project milestones are achieved more effectively. Comprehensive training programs for project managers and inspectors are essential to maximize the benefits of digital integration. Familiarity with new tools and processes ensures that the workforce is competent and confident in using advanced technologies, leading to better adoption and more effective use of digital tools in project management.

To fully leverage the capabilities of BIM and data visualization technologies, further improvements are recommended. These include developing faster report generation capabilities within StreamBIM to reduce reliance on external tools, better integration of 3D views to provide more detailed and accurate inspection data, merging workflows for related disciplines to streamline processes and reduce inefficiencies, and implementing comprehensive training programs to ensure that all users are proficient with the new systems and tools. The integration of StreamBIM with Power BI represents a significant advancement in construction project management, offering practical solutions to common challenges and paving the way for more efficient and effective project delivery. By embracing these digital tools, the construction industry can enhance data accuracy, streamline communication, and ultimately achieve higher standards of project quality and efficiency. Future research and development should focus on refining these technologies and expanding their application to further improve construction management practices.

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