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THE ROLE OF FINANCIAL DIGITAL TWIN IN THE SUPPLY CHAIN MANAGEMENT

Anjali Vaghani[1], Zhaoqing Gong[2], and Michael Henke[1]

[1]Chair of Enterprise Logistics, TU Dortmund University, Dortmund, GERMANY
[2]RIF Institute for Research and Transfer e.V., Dortmund, GERMANY

ABSTRACT

As supply chains undergo accelerated process of globalization and gain complexity, it becomes evident that conventional approaches to financial management are no longer adequate. The reliance on historical data, traditional budgeting, and delayed insights impede the accuracy of financial forecasting, management of cash flow, and mitigation of risk. This paper presents an exploration of the concept of a financial digital twin, which effectively serves as a digital representation of the financial processes of a supply chain by integrating near real-time data. The objective of this paper is to examine the limitations of traditional financial management practices and to examine how utilization of digital twin can revolutionize the practice of financial management. Additionally, the paper investigates the benefits and potential application of financial digital twins within supply chain. The paper is designed to provide experts with comprehensive understanding of the technology that holds the potential to transform financial supply chain management.

1 INTRODUCTION

Modern supply chain management is an intricate web that spans geographical boundaries, with vast interconnected networks spanning global suppliers, intricate logistics, and multifaceted production processes (Ivanov et al. 2019). Supply chains have become increasingly complex, and visibility has become poor (Cornander et al. 2023). This complexity, coupled with market volatility and unpredictable disruptions, exposes organizations to significant financial risks (Sodhi and Tang 2012). To manage this, decision-makers rely on a suite of Supply Chain Management tools. However, existing paradigms often suffer from the inadequate integration of real-time financial data (Waller and Fawcett 2013). Keeping track of costs, cash flow, and potential financial risks in real-time has become a major hurdle for enterprises operating in this space. The concept of digital twins offers a potential answer. Digital twin are the digital representation of physical assets, processes, or systems, continuously updated with real-world data through sensors and connected technologies (Tao et al. 2018; Roßmann and Schluse 2020).

The advent of the Internet of Things, cloud-computing technologies, artificial intelligence, and big data have facilitated the effective implementation of digital twins for complex systems (Kulac et al. 2022). Supply chain systems have already begun leveraging the capabilities of digital twins. Enterprises can access real-time data and information about internal and external processes effortlessly through the utilization of digital twins. As stated by the Association for Supply Chain Management (2021), organizations with business models incorporating real-time data monitoring, regular risk reviews, and incident management strategies implemented prior to the COVID-19 pandemic experienced a reduced prevalence of chronic disruptions within their supply chains during the pandemic. Regardless of which viewpoint one adopts, digital twin technology has been met with considerable interest from both

practitioners and academia. At present, this technology is utilized across an array of industries, enabling the creation of accurate virtual representations of objects and simulations of operational processes.

Experts predict that digital twins will become increasingly popular among large companies, with over 40% expected to incorporate it into their projects by 2027 (Attran and Celik 2023). The market size for digital twin is also expected to grow significantly, with an estimated $8 billion in 2022 and a projected 25% Compound Annual Growth Rate from 2023 to 2032. Another report indicated that the digital twin market will expand by nearly $32 billion from 2021 to 2026 (Attran and Celik 2023). Additionally, a 2022 study found that nearly 60% of executives in various industries plan to integrate digital twins into their operations by 2028 (Attran and Celik 2023). According to research, digital twins were expected to be utilized in critical applications by half of large industrial firms by 2021 (Attran and Celik 2023). A significant 62% of companies surveyed consider digital twin technology as a crucial factor for the successful implementation of Industry 4.0 strategies (Lindner 2023). According to the 2022 report on digital twins, a majority of organizations (57%) have identified that one of the primary motivators for investing in digital twins is to enhance their sustainability (Hasan 2023). Furthermore, more than half of the organizations (51%) believe that digital twins can help them achieve their environmental sustainability objectives (Hasan 2023). The manufacturing industry is anticipated to dominate the usage of digital twin applications by 2025. As the manufacturing industry increasingly focuses on reducing costs and enhancing supply chain operations, digital twin technology is predicted to experience significant growth in the coming years. By 2025, approximately 70% of manufacturers are projected to utilize digital twins to perform what-if analysis (Lindner 2023). As a result, the digital twin technology market was valued at $6.9 billion in 2022, with expectations that it will reach $73.5 billion by 2027, representing a CAGR of over 60% (Markets and Markets 2023). Based on existing research on the simulation of digital twin technology, it has become evident that digital twins showcase key features, including interconnectivity, scalability, real-time responsiveness, precision, and a closed-loop system (Yassin et al. 2023). When applied in industry and manufacturing, the primary function of digital twin technology is to manage and predict the entire product life cycle, which includes various interconnected processes such as product production and sales, as well as capital management. While digital twins have gained attention in areas like manufacturing and product lifecycle management, their potential to transform financial decision-making within supply chain management is less explored.

This paper presents the concept of a financial digital twin, which is a dynamic data-driven model that represents the financial health of a supply chain. In Section 2, we begin by discussing the challenges associated with traditional financial management practices in enterprises. Within this section, we then explore the trade-offs between operational and financial events. By establishing a connection between operational metrics and financial metrics in the supply chain, organizations can make more holistic decisions, optimize performance, and facilitate better strategic choices across the entire supply chain management process. In Section 3, we provide an overview of digital twins and their applications in the context of the supply chain. In Section 4, we introduce the concept of financial digital twins and discuss its applications across the supply chain. The paper concludes in Section 5 with a discussion of the limitations and considerations associated with financial digital twins.

2 MOTIVATION

2.1 Traditional Financial Management Challenges

Even during regular business operations, financial reporting can be impacted by uncertainty. Assumptions and valuations that underpin financial reporting are inherently uncertain (Hüttche 2023). Despite this, the going concern principle remains applicable, and companies plan for their continued operation in the foreseeable future. During times of supply chain crisis, uncertainty can be heightened, potentially casting

doubt on the entity's going concern status. This can have implications for financial statement preparation and reporting. Collecting financial data can be a time-consuming task (Nduokafor et al. 2024). Traditionally, generating financial reports, such as a quarterly sales forecast, could take companies a month or more. When business conditions changed, leaders would require updates, which could mean finance teams working late into the night to gather data from various sources. The primary benefit is providing timely insights for decision-makers, but the initial challenge is often obtaining the necessary real-time data (Soleimani 2018). Most legacy software systems do not provide real-time data, and many finance teams are still manually retrieving financial information from outdated spreadsheets or systems that require extensive reconciliation (Gagliordi 2023; Tawfik et al. 2023; Saha et al. 2020). As accurate planning and overall analysis rely on timely financial data, it's critical to have access to up-to-the-moment data as quickly as possible. A financial management system that provides greater access to real-time data is essential for a proactive financial management strategy, as it enables leaders to make decisions based on an organization's true financial health and operating performance (Dimitriu and Matei 2015).

Another significant obstacle in managing cash flow lies in the ability to gain full visibility into liquidity factors. Without this transparency, it is difficult to predict the amount of cash that will be available in the future to meet financial obligations. Cash flow challenges can also arise from various global operations, delayed customer payments, seasonal fluctuations in sales and costs, loan payment schedules and conditions, and misalignment with revenue recognition or expense accrual (Wang et al. 2022). To address these issues, it is essential to establish efficient receivables and payables processes, as well as attain high levels of transparency in sourcing and purchasing data to inform optimal decision-making.

At large global enterprises, managing operational complexity can be a common challenge caused by a vast product portfolio and a large number of employees to oversee (Gagliordi 2023). However, financial management can become even more daunting when finance processes and systems add to that complexity instead of providing clarity for business managers. For multinational organizations, navigating diverse regulatory environments and managing financial operations across different regions can be incredibly difficult.

Inefficient and ineffective financial processes can lead to complex operations that impede your company's financial reporting and analysis. Manual data entry and a lack of standardization often cause delays in obtaining insights that are crucial for improving financial performance. These manual processes are time-consuming, prone to errors, and limit the ability to conduct in-depth analysis and strategic thinking (Tawfik et al. 2023; Saha et al. 2020). Financial management teams often find themselves occupied with tasks that could be automated, such as invoice matching, which limits their capacity to focus on activities that support the company's financial goals. Slow and manual processes also hinder agility by taking up valuable time that could be used to respond to financial results. Moreover, manual tasks are less adaptable to changes in business needs, market conditions, or regulatory requirements.

The current process of decision-making is additionally subject to the influence of the state of equilibrium attained by operational selections and financial occurrences. In the following subsection, we shall undertake a brief discussion of this subject.

2.2 The Trade-off between Operational Decisions and Financial Decisions

“Operations and finance are two sides of the same coin” (Zhao and Huchzermeier 2018, pg 8). Operational management sets the groundwork for financial performance, while corporate finance supports real investments in operations (Li et al. 2022; Boujrouf et al. 2024). A symbiotic relationship exists between these two functions, with each playing a crucial role in driving business growth and profitability. Therefore, it is imperative for organizations to prioritize the integration of these functions to achieve optimal results and long-term sustainability. Still, the relationship between operational flow and financial

flow is often overlooked, resulting in decisions that are based on incomplete information (Protopappa-Sieke and Siefert 2010). Operations managers focus on making operational decisions related to inventory, service levels, and capacity needs to drive financial performance in terms of profit, working capital requirements, and return on investment. On the other hand, financial managers make decisions related to desired financial performance, which may constrain operational performance (Protopappa-Sieke and Siefert 2010). Therefore, in addition to operational metrics, financial data is also essential for making informed decisions (Murphy et al. 2020). The trade-off between operational decisions and financial decisions is not explicitly addressed by current practices, as companies are unable to predict the impact of a decision on both operational and financial aspects (Zhao and Huchzermeier 2018). This unbalanced approach leads to the absence of a comprehensive and cohesive view of organizational performance (Kaplan and Norton 1992). Therefore, it is extremely crucial to consider both operational and financial aspects while making decisions that affect an organization's overall performance.

Many companies are now proactively looking for ways to synchronize their financial (e.g., how much to factor) and operational (e.g., how much to produce) decision-making processes to enhance their overall profitability (Lekkakos and Serrano 2016). These decisions are typically managed by different departments within the organization. The goal is to optimize their returns by making the most informed decisions possible. Furthermore, certain organizations depend extensively on their internal capital to fund minor investment ventures. In light of this, it is just as critical to evaluate the amount of cash that can be liberated from their working capital without compromising their service level (Lekkakos and Serrano 2016). Therefore, by combining operational and financial aspects, not only a holistic view of the organization’s performance achieved but also enables a more balanced evaluation of the supply chain’s effectiveness and efficiency.

3 DIGITAL TWIN

3.1 The Rise of Digital Twin

Digital twin technology has been gaining significant attention in recent years, owing to its ability to simulate and analyze the behaviour and performance of physical assets. With the increasing trend of digitalization, this technology has evolved rapidly in terms of both scale and scope, offering new opportunities for a wide range of industries. Despite its potential, digital twin technology has faced challenges due to misconceptions about its capabilities and limitations, which have been fueled by its rapid ascent in popularity. It is often said that digital twin technology played a crucial role in resolving the critical challenges faced during the Apollo 13 mission. This has led to captivating stories that highlight the potential of digital twin technology in crisis management. However, such accounts must be approached with scrutiny. Michael Grieves, a key figure in the development of the digital twin concept, has explicitly denied any direct link between the technology's origins and the Apollo program. In 2022, he clarified this misconception, emphasizing the importance of distinguishing between factual history and compelling anecdotes (Grieves 2024).

Before exploring other aspects of digital twin technology, it is important to review its origins. Understanding where it comes from can help us better understand where it is headed. To do this, it is vital to differentiate between the term "digital twin" and the underlying concept. The concept and its model were first proposed by Grieves in 2002 as a foundation for Product Lifecycle Management (PLM). The terminology evolved from "Conceptual Ideal for PLM" in 2002 to "Mirrored Spaces Model" and "Information Mirroring Model" in subsequent years. John Vickers coined the term "digital twin" in 2010 (Grieves 2023), which Grieves formally adopted in a well-cited manufacturing white paper published in 2014 (Grieves 2014). As well known, the concept itself consists of three main characteristics:

- Physical products existing in physical space,
- Their digital representation in virtual space, and
- The connection that bridges the physical and virtual spaces.

Traditionally, research and testing involved creating physical prototypes. However, the digital twin concept is revolutionizing this approach by shifting these tasks to the digital realm. This innovative method involves digitally modelling, testing, and validating products instead of building their physical counterparts. The advantages of this transition are numerous: it reduces costs associated with materials, energy, and time while also expediting the development process. Initially, the development of the digital twin concept was constrained by a lack of computing power. Nevertheless, with the current exponential growth of computing power, the digital twin concept has regained broad interest and is progressing rapidly.

3.2 Digital Twin in Supply Chain

Initially conceptualized for tangible industrial products, the digital twin has broadened its reach to encompass intangible aspects such as processes, supply chains, and financial products. In modern supply chain management, the digital twin represents a transformative approach to optimizing the supply chain operations and decision-making processes. Unlike traditional supply chain management tools, which are often static and operate in silos, digital twins introduce a fundamental shift towards real-time visibility and integrated data analytics across different segments of the supply chain. This evolution marks a departure from conventional practices, offering a more dynamic, interconnected, and transparent method to manage and optimize supply chain operations.

Diverging from traditional systems, digital twin leverages the expanding capabilities of the Internet of Things (IoT) technology. This integration allows for the collection of large volumes of data to become both technically feasible and cost-effective (Kamble et al. 2022). By harnessing IoT, digital twins can access a vast array of data points in real-time, from operational performance to environmental conditions.

The utilization of real-time data forms a vital backbone for enhancing decision support across various facets of production operations. This encompasses areas such as production planning, where accurate, up-to-the-minute information can significantly optimize schedules and resource allocation (Qin et al. 2021). In maintenance, real-time data can predict equipment failures before they occur, allowing for preemptive action that minimizes downtime (Khajavi et al. 2019). Inventory management benefits from a precise understanding of stock levels and demands, leading to reduced waste and improved efficiency (Maheshwari and Kamble 2022). Logistics planning also sees improvements, with the ability to dynamically adapt to changes in supply chain conditions, ensuring that materials and products are moved efficiently (Qiu et al. 2023).

Digital twin technology profoundly impacts operational performance metrics within supply chains by significantly enhancing efficiency, reliability, adaptability, and sustainability. By optimizing resource utilization, reducing waste, and streamlining process flows, digital twins lead to quicker production cycles, cost reductions, and leaner supply chains, thereby boosting efficiency. They enhance reliability through failure prediction and risk identification, ensuring adherence to production schedules, maintenance of quality standards, and shortened delivery times, which collectively heighten customer satisfaction. Their capacity to simulate diverse scenarios allows supply chains to swiftly adapt to market changes, customer needs, and supply fluctuations, maintaining a competitive edge. Furthermore, by promoting sustainable practices through optimized resource use and waste minimization, digital twins assist companies in achieving environmental goals and enhancing their sustainability profile, showcasing their comprehensive impact on operational performance metrics.

4 FINANCIAL DIGITAL TWIN

A financial digital twin is a virtual model that represents an organization's financial metrics, processes, and interdependencies across the entire product lifecycle and supply chain (Rodt et al. 2022). It integrates real-time financial data with pertinent non-financial information, such as operational data, market trends, and customer insights, to facilitate comprehensive decision-making, simulate "what-if" scenarios, and improve analysis. This twin enables businesses to holistically assess their financial performance, identify areas of improvement, and optimize their operations to drive growth and success. By leveraging the capabilities of a financial digital twin, organizations can gain valuable insights into their financial health and make informed decisions that lead to improved performance and profitability. Figure 1 presents the financial digital twin structure, which is inspired by the works of Malakuti et al. (2020) and Wang et al. (2022). Analogous to the digital twin concept, a digital or virtual realm would be employed, which further consists of a network layer and a simulation layer. The network layer encompasses data support services for the simulation and application layers. The simulation layer comprises features such as real-time monitoring, decision optimization, system prediction, scenario modeling, and testing. In the financial application realm, various finance-related operations can be mapped in real-time in the digital space. Potential applications include scenario testing, capital allocation decision management, Environmental, Social, and Governance (ESG) impact calculations, and others.

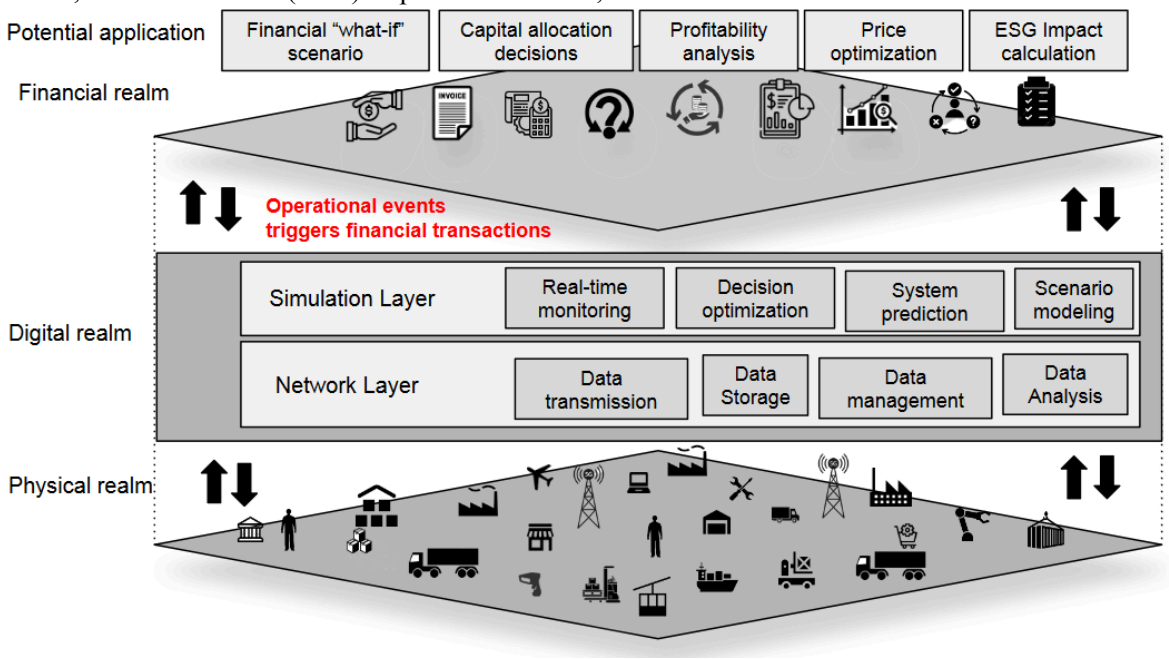

Figure 1: Financial digital twin structure.

The concept is still in its nascent stage and there is a dearth of research conducted in this domain. Let's examine some of the research undertaken in the financial services industry pertaining to the concept of the digital twin.

The framework for a financial digital twin was developed by authors in a paper (Lynch et al. 2023), which integrates fund allocation and accounting with project acquisition in real-time. It allows the owner to automate funding allocation tasks and to synchronize change management while ensuring compliance with funding restrictions. The primary aim of this framework is to consolidate and continually optimize the efficient use of accurate financial information at all stages of the capital asset lifecycle by leveraging rule-based knowledge management. This is accomplished through digital twin integration and automation.

A use case was developed based on this framework to demonstrate and evaluate the financial digital twin, which was found to have the potential for more efficient information management and support for decision-making through enterprise-level data integration (Lynch et al. 2023).

In the work of (Schulte and Schipp 2022), it is suggested that the integration of physical and financial digital twins results in a comprehensive representation that not only depicts the flow of goods and the corresponding financial transactions but also elucidates the value-added contributions of individual segments within the supply chain. This holistic perspective, supported by reliable data, facilitates coordinated financing for accounts payable, inventory management, and accounts receivable, thereby leading to substantial risk mitigation and cost reductions across the supply chains.

4.1 Potential Applications of Financial Digital Twin

In this section, we present several potential applications of financial digital twins with the aim of encouraging further research in this area within the context of the supply chain.

4.1.1 Scenario Planning and Modelling

Digital twins can be created for both products and services. Developing digital twins for products provides valuable insights into the product's life cycle and future performance. Additionally, sensors can assist in constructing digital twins of facilities, enabling the development of facility layouts without physical alterations (Uhlemann et al. 2017).

The supply chain digital twin is a valuable tool that is utilized when an environment is riddled with risks and uncertainties. It is particularly helpful for conducting "what-if" analysis, as well as assessing the potential benefits and impacts of various scenarios (Barat et al. 2022). This digital twin is widely applied due to its ability to model complex systems, provide insights, and enable decision-making in a dynamic environment (Oliveira et al. 2019). Notably, digital twin plays a crucial role in Walmart's inventory management system (SMR 2023). To begin with, businesses create a digital replica of their stores, complete with a virtual inventory. They then scrutinize and enhance inventory levels, product placement, and restocking tactics. By running simulations of various scenarios, businesses can evaluate the effects of demand fluctuations, seasonal changes, or supply chain interruptions on inventory management. The adoption of digital twins has enabled Walmart to enhance customer experiences and augment operational efficiency.

Envision a scenario where enterprises leverage digital twins for strategic planning, hypothesis experimentation, optimized decision-making and proactive risk identification across financial services and supply chain processes. Through "what-if" scenarios, enterprises can quantify the financial impact of disruptions, such as supplier changes, transportation delays, geopolitical instability, or natural disasters. These complex, multi-variable scenarios can easily be simulated. Consider the implications of interest rate fluctuations, competitor entry, or labor strikes on the financial stability of the enterprise. Simulating market crashes, currency shifts, or interest rate adjustments reveals the resilience of the supply chain and its financing against significant shocks. Such simulations facilitate proactive contingency planning and mitigation strategies. Additionally, by continuously integrating supply chain data, the digital twin can detect anomalies or patterns indicative of potential financial risks, such as declining supplier performance.

Now to attain financial planning objectives, a methodical process must be followed (See Figure 2, which is inspired by Lindquist and Haas (2021)). The preliminary stage entails the identification of significant financial focal issues that call for scrutiny. These constitute the fundamental concerns that will undergo evaluation through scenario analysis. Thereafter, it is imperative to establish the organization's financial planning objectives or goals. Subsequently, it is also important to determine the operational events that are directly linked to the financial focal issues identified. Additionally, all stakeholders or entities involved in these focal issues must be recognized. These stakeholders possess the capability to

exert influence upon or be directly impacted by the focal issues. A comprehensive assessment is necessary to address every aspect of the focal issues and their actors. The linkage and relationship between the actors must be analyzed, and a system must be defined through mapping. The fifth step necessitates gathering financial and operational data pertinent to the focal issues. Subsequently, key uncertainties, which are alternatives to the focal issues and may significantly impact them, must be identified. A description of their significance and interrelatedness to the focal issues is essential. After setting the stage, scenarios are developed based on the preceding steps, encompassing focal issues, actors, assessment, and key uncertainties. Scenarios typically take the form of narratives that originate from past events and evolve into hypothetical future events. Once the scenarios are developed, they must be tested by implementing changes in the created systems. Scenario testing can be conducted using models that alter the system based on the scenario and provide an outcome. The outcome of the testing is then evaluated and compared to the current organizational and environmental conditions.

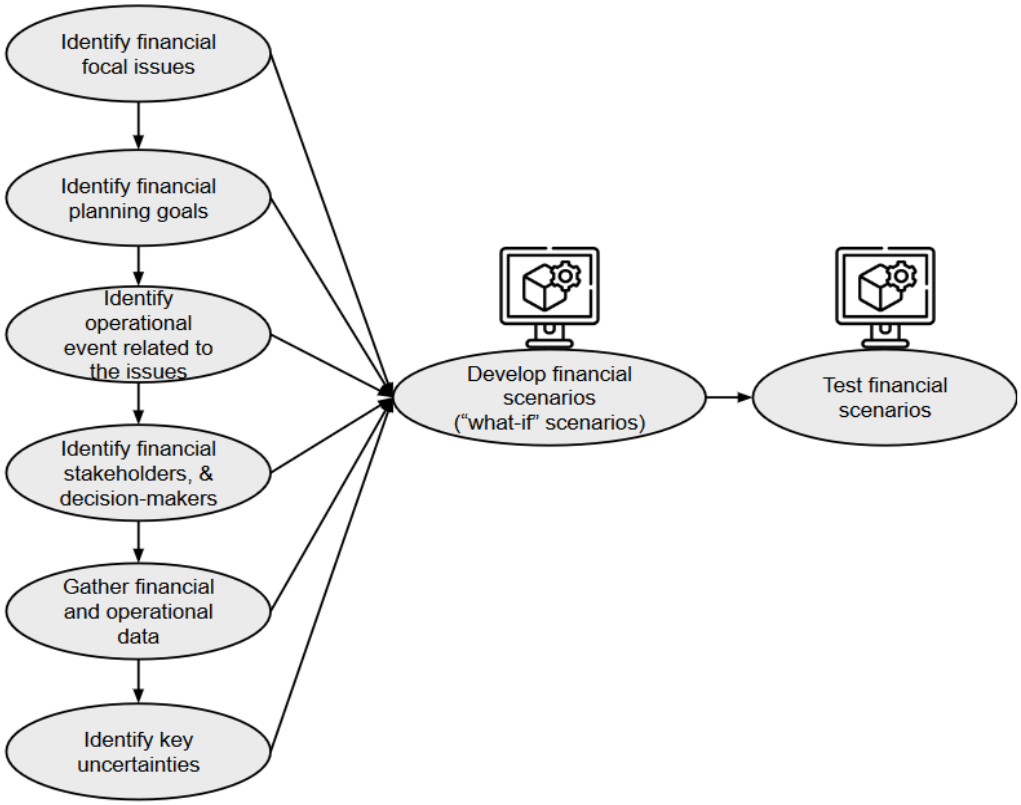

Figure 2: Financial scenario planning.

4.1.2 Integrated Cost and Profitability Analysis

Within the realm of supply chain management and production operations, digital twins have emerged as invaluable tools, offering unprecedented transparency into granular and real-time operational data. By leveraging similar capabilities, finance functions can establish a framework for comparative analysis of granular data across various functional units (Rodt et al. 2022). Consequently, this approach has the potential to enhance the efficiency and quality of decision-making at the enterprise level.

Real-time profitability analysis entails an ongoing evaluation of the financial viability of supply chain activities. Unlike quarterly reports, this analysis provides immediate insights (at least near real-time) into profitability. It facilitates data segmentation, for example, by product line, customer segment, and region,

enabling the identification of trends and patterns. This approach allows for prompt decision-making rather than delayed reactions. For instance, should a particular product line experience a sudden decline in profitability, an immediate investigation and corrective measures can be undertaken. Additionally, if a specific customer segment exhibits unexpectedly high profitability, sales and marketing strategies can be swiftly adjusted to capitalize on this trend. The financial digital twin strives to establish a direct correlation between operational activities and financial outcomes. It necessitates comprehensive cost data that reflects the supply chain's complexity and up-to-date data flows to avert outdated figures. Real-time profitability analysis serves as a vital component for accurate modelling.

4.1.3 Capital Allocation Optimization

The current state of capital management poses significant challenges for enterprises. The capital chain is fragile, turnover is difficult, and the structure is unreasonable (Jinchang and Ruizhen 2012). The presence of multiple issues, including idle funds and suboptimal utilization rates, requires prompt attention. Improving the level of capital management is crucial for successful enterprise digitization (Stice et al. 2017). This requires effective coordination of funds and collection, processing, and analysis of relevant financial data. Mastering these critical aspects is paramount to optimizing capital management and control.

Authors in the paper (Wang et al. 2022) posit a scenario where pursuing enterprise objectives requires careful allocation of working capital. Every stage of the production process — from the procurement of raw materials to the coverage of production costs and the eventual sale of the product — entails financial decision-making. To facilitate informed choices, it is crucial to gather historical and real-time information about enterprise operations and market conditions utilizing intelligent terminal equipment and market information collection. Furthermore, with the aid of a twin modelling mechanism, the simulated operation of predetermined production and operation schemes can be adjusted and optimized based on feedback and iterative optimization. This approach provides businesses within the supply chain with a simulated environment to test and fine-tune their strategies, mitigating potential losses and enhancing overall efficiency and furthermore, freeing a portion of the organization's cash flow. Capital that is released through the optimization of working capital can then be utilized for fixed asset investments or additional capital expenditures (Schulte and Schipp 2022).

4.1.4 Pricing Optimization

In Section 4.1.1, the use of digital twins to envision various scenarios in which businesses can benefit from their implementation was discussed. This approach facilitates strategic planning, hypothesis testing, and proactive risk identification across financial services and supply chain processes. This strategy further can be used for optimizing product pricing. Simulating demand and revenue variations through price elasticity testing can determine the optimal price point, enabling pricing optimization. Moreover, digital twin technology can be leveraged for competitor analysis, facilitating comparative assessments with rivals. This analysis enables the forecasting of market share and revenue outcomes resulting from price adjustments.

4.1.5 ESG Impact Calculation

In the financial markets, a growing trend among participants involves incorporating Environmental, Social, and Governance (ESG) criteria into their investment decisions (Busch et al. 2016). This phenomenon is attributable to several factors, including heightened awareness of the impact of climate change and other environmental concerns, increasing demand for sustainable products and services, and

escalating regulatory pressure on companies to enhance their ESG performance. Despite this growing interest in ESG investing, there is limited evidence of a substantial shift towards more sustainable business operations by companies (Busch et al. 2016). This can be attributed to various factors, such as the absence of clear and consistent ESG standards, the challenges associated with measuring and reporting ESG performance, and the short-term focus prevalent in many businesses.

Also, the identification and quantification of ESG aspects along a company's supply chain is challenging due to a lack of transparency (Schulte and Schipp 2022). Companies often lack visibility into their supplier networks, especially across international supply chains. This issue contradicts the increasing relevance of sustainability risks and ESG matters in supply chains. Sustainability affects companies and their supply chains differently. Studies suggest that most environmental pollution, social grievances, and governance violations occur in supply chains (Carbon Disclosure Project 2019; Berg et al. 2020). Reliable data across all supply chain stages is necessary for translating sustainability goals into specific measures. Transparency about physical goods flow and understanding supply chains are crucial for setting targeted financial incentives. One of the primary advantages of the financial digital twin is its ability to facilitate trade-offs between profitability and sustainability for enterprises. Through a comprehensive understanding of the full cost of their products and services, companies can make well-informed decisions regarding the reduction of their environmental impact without compromising profitability. Additionally, the financial digital twin can be employed to support effective reporting to external stakeholders, thereby enhancing trust with customers, investors, and other stakeholders by providing transparent information pertaining to environmental and social performance (Rodt et al. 2022). The financial digital twin offers a means for companies to overcome these challenges and transition to more sustainable business operations. By presenting a holistic view of the financial and non-financial impacts of their products and services, the financial digital twin empowers companies to make informed decisions regarding the enhancement of their ESG performance (Rodt et al. 2022; Schulte and Schipp 2022).

5. CONCLUSION

In this paper, we embark on a discourse on the traditional financial management challenges encountered. We also shed light on the implications of the trade-off between operational and financial decisions within the supply chain. Subsequently, we introduce the concept of the financial digital twin. Furthermore, we explore potential applications of financial digital twins, such as scenario planning, pricing optimization, integrated cost, capital allocation optimization, profitability analysis, and ESG impact calculation. In this section, we also discern some of the challenges associated with integrating the financial digital twin into the supply chain.

The primary challenge is data integration. Financial digital twins must seamlessly integrate data and information from diverse accounting systems and databases into the digital twin, such as WMS (Warehouse Management Systems), PLM (Product Lifecycle Management) systems, ERP (Enterprise Resource Planning) software, CRM (Customer Relationship Management) systems, Supply Chain Management systems, and external market information, etc. The second challenge is security and data governance. Financial data is highly sensitive, and ensuring that the digital twin possesses rigorous security and access controls and complies with data privacy regulations is a formidable task.

The digital twin is most efficacious for financing and risk management when it integrates supply chain partners and their data (with appropriate security measures in place). This affords a more holistic and dynamic depiction. However, the supply chain is inherently complex. Integrating a financial digital twin into an intricate supply chain with multiple stakeholders further poses a significant challenge.

This paper provides an overview of the conceptual aspects underpinning the application of digital

twins in the financial services sector within the context of supply chain management. However, further investigation is necessary to explore the technical complexities and potential synergies with other relevant technologies.

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AUTHOR BIOGRAPHIES

ANJALI VAGHANI is a research assistant at the Chair of Enterprise Logistics at the TU Dortmund University, Germany, and a member of the research training group “Adaptation intelligence of factories in dynamic and complex environments” (GRK 2193). Her email address is Anjali.vaghani@tu-dortmund.de and her website is https://lfo.tu-dortmund.de/ueber-uns/mitarbeiter/anjali-v.

ZHAOQING GONG is a research assistant at the RIF Institute for Research and Transfer e.V., Dortmund, Germany, and a member of the research training group “Adaptation intelligence of factories in dynamic and complex environments” (GRK 2193). His email address is Zhaoqing.gong@rt.rif-ev.de, and his website is https://www.grk2193.tu-dortmund.de/project/zhaoqing-gong.

MICHAEL HENKE is the Professor and head of the Chair of Enterprise Logistics and Dean of the Faculty of Mechanical Engineering at the TU Dortmund University, Dortmund, Germany, and a managing director of the Fraunhofer Institute for Material Flow and Logistics, Dortmund, Germany. His email address is michael.henke@tu-dortmund.de, and his website is https://lfo.tu-dortmund.de/ueber-uns/mitarbeiter/michael-henke/.