

A Control Risk Template to address the risks with the implementation of prescriptive analytics



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Purpose: This study addresses the complex risks of implementing prescriptive analytics in vineyard management. It focusses on integrating diverse, previously isolated data resources into operational decisions in irrigation, nutrition and pest management. Aligning with the United Nations' Sustainable Development Goals (SDGs), this integration is crucial for optimising vineyard growth and production, and advancing precision agriculture techniques within the framework of sustainable agriculture. In this context, it introduces a Control Risk Template (CRT) to manage these risks effectively.

Design/methodology/approach: The study uses an exploratory research design and grounded theory methodology to conduct a comprehensive systematic literature review.

Findings/results: The findings demonstrate how the CRT can effectively identify, assess and manage the risks of deploying prescriptive analytics in vineyard management. This approach minimises risks and significantly improves decision-making and operational efficiencies in vineyard management, contributing to the advancement of sustainable agricultural practices.

Practical implications: This research offers valuable insights for vineyard managers and information technology (IT) governance leaders. It provides a robust model for enhancing vineyard management through advanced data-driven decisions. Implementing the CRT facilitates better resource allocation and improved crop health management, fostering a transition towards more sustainable agricultural practices.

Originality/value: This research suggests a comprehensive approach to integrating IT governance with practical agricultural operations, significantly contributing to academic research and industry practices. Moreover, the study delivers essential insights into the effective integration of prescriptive analytics in vineyard management, underscoring the transformative potential of IT governance frameworks in enhancing the sustainability and efficiency of vineyard management.

Keywords: COBIT; Control Risk Template; Fourth Industrial Revolution; IT governance; prescriptive analytics; precision agriculture; risk management; sustainable agriculture; vineyard management.

Introduction

Vineyard management is a critical component of the global agricultural sector, significantly contributing to economies through wine production, tourism, and employment (Anderson & Pinilla, 2018). The global wine industry was valued at approximately \$330 billion in 2023 and is projected to grow (Statista, 2024). Countries like France, Italy, and Spain lead in production and exports, underscoring the global importance of efficient vineyard practices (Statista, 2024).

In South Africa, the wine industry is vital to the economy. It contributes about ZAR56.5bn (approximately \$3.5bn) to the country's gross domestic product (GDP); about ZAR31bn from the Western Cape province and 270 363 jobs, both directly and indirectly, in the South African wine industry in 2019 (Wines of South Africa, 2019). The sector not only bolsters economic growth but also fosters rural development, tourism and international trade, making efficient vineyard management a matter of national significance (South African Wine Industry Information & Systems, 2023). Therefore, enhancing vineyard management practices substantially impacts the country's economic development and job creation.

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South Africa's and global vineyard management has traditionally relied on empirical knowledge and manual observations (Reynolds, 2022). While these methods have laid a solid foundation, they often fail to capture and analyse the complex data required to optimise modern viticulture's intricate variables such as fluctuating weather patterns, varying soil conditions and plant physiology dynamics (Kamangir et al., 2024). As the agricultural sector moves towards more data-driven methodologies, there is an evident need for a paradigm shift to improve productivity and sustainability, and to manage the risks associated with digital transformation effectively (Bongiiovanni & Lowenberg-Deboer, 2004).

Integrating advanced agricultural technologies, specifically through the implementation of prescriptive analytics (PA) in vineyard management, is pivotal in achieving enhanced efficiency and sustainability. Prescriptive analytics has the potential to revolutionise vineyard management by providing precise, actionable insights that enhance decision-making in crucial areas such as irrigation, nutrition and pest management (Petrović et al., 2024). For instance, optimising irrigation schedules based on predictive models can significantly reduce water usage – a critical consideration in water-scarce regions like South Africa (Schultz, 2016). These improvements can reduce waste and cost efficiencies and improve outputs, benefiting the sector's economic and environmental performance.

Moreover, the adoption of PA aligns with the United Nations' (UN) Sustainable Development Goals (SDGs), particularly those related to sustainable agriculture (Goal 2), clean water and sanitation (Goal 6) and responsible consumption and production (Goal 12) (United Nations, 2015). By integrating PA, organisations can enhance their sustainability practices from an integrated thinking perspective – considering environmental, social and governance (ESG) factors and a multi-capital outlook (Adams, 2017). This approach supports long-term sustainability and aligns with supra-national objectives and government policies to promote sustainable agricultural practices (Department of Agriculture, Land Reform and Rural Development, 2023). Achieving these goals assists organisations in meeting both national and international sustainability targets, thereby contributing to global efforts against climate change and resource depletion.

Countries with more advanced vineyard management systems such as those in Europe and North America, have demonstrated that integrating PA can significantly improve yield quality, operational efficiency and risk mitigation (Statista, 2024). By drawing parallels between developed and developing countries, this study highlights the potential for South Africa to adopt and adapt these technologies to its local context. This not only bridges the technological gap but also places the research in a global context, showcasing its contribution to the advancement of vineyard management systems worldwide.

However, introducing such advanced technologies brings a host of risks; particularly concerning data integrity, security and privacy, which must be meticulously managed to harness their full potential (Lepenioti et al., 2020). The core challenge in adopting PA within vineyard management is ensuring robust information technology (IT) governance to integrate diverse and complex data streams effectively. With proper risk management strategies and improved control systems, the sector may avoid issues that could negate the benefits of technological advancements.

This research aims to develop a Control Risk Template (CRT) to address these challenges. This tool incorporates the Control Objectives for Information and Related Technology (COBIT) framework to address the inherent risks of implementing PA in vineyard management while maintaining high standards of IT governance (ISACA, 2018). By integrating isolated data sources – such as irrigation, nutrition and pest management – the CRT facilitates a unified template for seamless data flow and comprehensive analysis. This integration is critical for enhancing decision-making processes; ultimately improving grapevine yield and quality by leveraging interconnected data.

The CRT addresses gaps in current vineyard management practices, often lacking comprehensive data governance strategies (INRIA, 2022). By applying this template, organisations can refine decision-making processes, ensure compliance with stringent IT governance standards and achieve cost efficiencies through reduced waste and improved outputs. The CRT provides a unified framework for seamless data flow and comprehensive analysis, enhances operational efficiency and secures data processes. As new technologies enter the agricultural market, the CRT sets a new benchmark for applying IT governance principles in precision agriculture; particularly in developing countries like South Africa.

This study offers valuable insights for vineyard managers and IT governance leaders by providing a structured approach to integrating advanced technologies while managing associated risks. By aligning vineyard management practices with UN SDGs and ESG considerations, the research contributes to long-term sustainability and economic growth. Furthermore, by making a more transparent link between the contributions in developed and developing countries, the study better positions itself as a valid contribution to the global discourse on vineyard management and governance systems; potentially influencing future research and industry practices.

This article proceeds as follows. The next section offers a comprehensive literature review to establish the research gap by critically examining existing studies at the intersection of viticulture and PA. Specifically, it highlights the need for a comprehensive and structured approach to integrating advanced technologies in vineyard management while effectively managing the associated risks through an IT

governance framework in the form of a template. The ensuing section explains the methodological approach, including the research design, data collection and analysis techniques. The subsequent section presents the findings before explaining the management implications. The article concludes with limitations, avenues for future research and the conclusion.

Literature review

The need for an integrated template to mitigate implementation risks

Vineyard management is undergoing a significant transformation because of technological advancements, increasing emphasis on sustainability and the need for robust corporate governance (Sánchez-García et al., 2024). The integration of PA presents an opportunity to optimise vineyard operations by providing precise, actionable insights (Petrović et al., 2024). However, implementing such advanced technologies introduces complex IT-related risks such as data integrity, security and privacy issues (Lepenioti et al., 2020).

It is essential to develop a template that ensures appropriate IT governance practices are in place and aligned with corporate governance principles, promoting integrated thinking and achieving sustainability goals while implementing advanced technologies such as PA within vineyard management. This paper will examine existing studies at the intersection of viticulture, corporate governance and sustainability, highlighting the need to define the building blocks in the proceeding section that form the foundation of our CRT.

Before delving into the specific building blocks of the CRT, it is crucial to understand the interplay of corporate governance and the King IV code, integrated thinking from the Integrated Reporting Framework and sustainability based on the SDGs, specifically in the context of vineyard management. These concepts provide the indirect foundational pillars (illustrated in Figure 1) that guide the effective implementation of advanced technologies like PA through the use of the CRT to ensure optimal grapevine growth and production levels while maintaining proper IT governance practices.

Corporate governance and the King IV code

Effective corporate governance is crucial in managing the risks associated with implementing advanced technologies

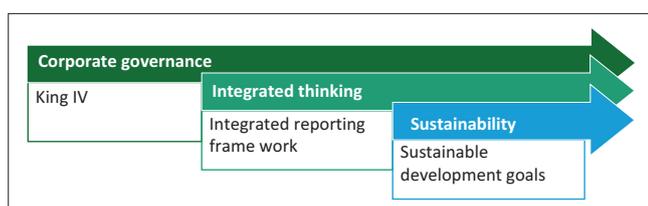


FIGURE 1: Foundational pillars of the Control Risk Template.

(King Committee on Corporate Governance, 2016). The King IV Code emphasises ethical leadership, sustainability and integrated thinking (Institute of Directors in Southern Africa, 2016). Although this article does not analyse each principle of the King IV Code in detail, it indirectly addresses these principles by incorporating the core aspects of corporate governance into vineyard management through the development of the CRT. By aligning the CRT with the overarching principles of the King IV Code, the article ensures that the adoption of PA aligns with ethical considerations and contributes to sustainability objectives.

To illustrate this alignment, Table 1 outlines each principle of the King IV Code and briefly indicates how the CRT addresses or aligns with it in vineyard management.

Visser and De Langen (2006) highlight the importance of governance in the wine industry, demonstrating that solid governance structures can enhance competitiveness and sustainability. Their study of the Chilean wine industry shows how quality governance leads to improved innovation and market positioning. Similarly, Saisset et al. (2023) examine governance, innovations and sustainability in the French wine industry; finding that governance structures significantly impact adopting sustainable practices and technological innovations.

By aligning with these principles, the CRT ensures that the integration of PA into vineyard management is conducted responsibly, ethically and in a manner that supports sustainable value creation. This alignment mitigates risks associated with technology implementation and enhances the organisation's corporate governance practices, contributing to improved competitiveness and stakeholder trust.

Integrated thinking as a theoretical foundation in vineyard management

Integrated thinking is a holistic approach that considers the interdependencies between various resources and relationships an organisation relies on to create value over time (International Integrated Reporting Council, 2013). This approach is essential in vineyard management, where implementing PA requires balancing multiple capitals – financial, manufactured, intellectual, human, social, relationship and natural capitals (Herath et al., 2021).

To illustrate how the CRT aligns with integrated thinking, Table 2 provides an overview of how each of the six capitals is considered within the CRT in the context of vineyard management.

Dimes and De Villiers (2023) identify the hallmarks of integrated thinking, emphasising the orchestration of resources to drive value creation. Applying integrated thinking in vineyard management allows for enhanced decision-making processes, ensuring that technological

TABLE 1: Alignment of King IV principles with the control risk template.

King IV Principle	Alignment with the CRT
Principle 1: The governing body should lead ethically and effectively.	The CRT promotes ethical leadership by providing a framework that ensures decision-making in PA implementation is guided by ethical considerations, enhancing accountability and transparency in vineyard management.
Principle 2: The governing body should govern the organisation's ethics to support establishing an ethical culture.	Integrating ethical guidelines into the CRT supports establishing an ethical culture in which data integrity and responsible use of technology are prioritised in vineyard operations.
Principle 3: The governing body should ensure the organisation is considered a responsible corporate citizen.	The CRT encourages sustainable practices aligned with social and environmental responsibilities, reinforcing the organisation's reputation as a responsible corporate citizen through sustainable vineyard management.
Principle 4: The governing body should appreciate that the organisation's core purpose, risks, opportunities, strategy, business model, performance and sustainable development are all inseparable elements of the value creation process.	The CRT aligns PA implementation with the organisation's strategic objectives, ensuring that risk management, performance optimisation and sustainable development are integrated into the value creation process in vineyard management.
Principle 5: The governing body should ensure that the organisation's reports enable stakeholders to assess its performance.	By facilitating comprehensive data collection and analysis, the CRT enhances reporting accuracy and transparency; enabling stakeholders to make informed assessments of vineyard performance and PA outcomes.
Principle 6: The governing body should serve as the organisation's focal point and custodian of corporate governance.	The CRT provides a structured framework for the governing body to oversee PA implementation, reinforcing its role as the custodian of corporate governance in vineyard management.
Principle 7: The governing body should comprise the appropriate balance of knowledge, skills, experience, diversity and independence.	Implementing the CRT requires a multidisciplinary team that promotes diversity and balances technology, viticulture and governance expertise to manage PA risks effectively.
Principle 8: The governing body should ensure that its arrangements for delegation promote independent judgement and assist with the balance of power and effective discharge of duties.	The CRT outlines clear roles and responsibilities in PA processes, supporting effective delegation and independent judgement while maintaining accountability in vineyard management decisions.
Principle 9: The governing body should ensure that the evaluation of its performance supports continued improvement.	The CRT includes mechanisms for monitoring and evaluating PA implementation, enabling the governing body to assess its effectiveness and identify areas for improvement in governance practices.
Principle 10: The governing body should ensure that appointing and delegating to management contribute to role clarity and effective exercise of authority.	Defining specific responsibilities within the CRT enhances role clarity, ensuring management can effectively exercise authority in implementing PA in vineyard operations.
Principle 11: The governing body should govern risk to support the organisation in setting and achieving strategic objectives.	Risk management is a core component of the CRT. It aligns PA implementation with strategic objectives and ensures risks are identified, assessed and mitigated effectively in vineyard management.
Principle 12: The governing body should govern technology and information to support the organisation in setting and achieving its strategic objectives.	The CRT specifically addresses IT governance by incorporating the COBIT framework, ensuring that technology and information systems used in PA support the organisation's strategic goals in vineyard management.
Principle 13: The governing body should govern compliance with applicable laws and adopted codes and standards.	Compliance is embedded in the CRT, guiding the implementation of PA in adherence to legal requirements and industry standards, thereby, reducing legal and regulatory risks.
Principle 14: The governing body should ensure that the organisation remunerates fairly, responsibly and transparently.	While the CRT does not directly address remuneration, it promotes transparency and responsibility in operational processes, indirectly supporting fair and transparent practices within the organisation.
Principle 15: The governing body should ensure that assurance services and functions enable an effective control environment.	The CRT enhances the control environment by providing assurance mechanisms for PA implementation including monitoring, auditing and continuous improvement processes in vineyard management.
Principle 16: In executing its governance role and responsibilities, the governing body should adopt a stakeholder-inclusive approach.	The CRT facilitates stakeholder engagement by promoting transparency and considering stakeholder interests in implementing PA, ensuring that decisions benefit all relevant parties in the vineyard ecosystem.

PA, prescriptive analytics; IT, information technology; CRT, Control Risk Template; COBIT, Control Objectives for Information and Related Technology.

TABLE 2: Alignment of the control risk template with the six capitals of integrated thinking.

Capital	Alignment with the CRT
Financial capital	The CRT enhances financial capital by optimising resource allocation and reducing operational costs through efficient PA implementation. Minimising waste and improving yield quality contribute to increased profitability and economic sustainability of vineyard operations.
Manufactured capital	By integrating PA into vineyard management, the CRT improves the utilisation and maintenance of physical assets such as equipment and infrastructure. It ensures that technological tools are effectively implemented, enhancing productivity and extending the lifespan of such assets.
Intellectual capital	The CRT fosters intellectual capital by promoting knowledge creation and innovation. It encourages the development of data analytics capabilities and accumulating expertise in PA, contributing to the organisation's collective intelligence and competitive advantage.
Human capital	Through training and development initiatives embedded in the CRT, employees enhance their skills in using advanced technologies. The CRT supports employee engagement and capacity building, improving job satisfaction and retaining skilled personnel in the vineyard industry.
Social and relationship capital	The CRT promotes transparency and ethical practices, strengthening relationships with stakeholders, suppliers, customers and the community. Aligning operations with societal expectations and fostering trust enhance the organisation's reputation and social licence to operate.
Natural capital	The CRT aligns with sustainability goals by optimising natural resources such as water and soil nutrients. Through PA, it supports environmentally responsible practices, contributing to the conservation of ecosystems and biodiversity in vineyard regions.

PA, prescriptive analytics; CRT, Control Risk Template.

implementations like PA contribute to long-term sustainability and value creation (Maroun et al., 2023). Moreover, integrated thinking highlights the link to corporate governance as a key pillar; suggesting that appropriate governance structures are necessary to foster an environment where integrated thinking can thrive (Dimes & De Villiers, 2021).

By aligning with the six capitals of integrated thinking, the CRT ensures that the implementation of PA in vineyard management is holistic and contributes to value creation

across multiple dimensions. This alignment facilitates better decision-making and strategic planning, ensuring the organisation's resources are effectively leveraged to achieve long-term sustainability and success.

Sustainability in vineyard management

Sustainability is a critical concern in modern vineyard management. The UN SDGs emphasise the need for sustainable agriculture practices (United Nations, 2015). Integrating PA aligns with UN SDGs related to sustainable

agriculture, clean water and sanitation, and responsible consumption and production. Legun and Sautier (2018) examine sustainability programmes in New Zealand winegrowing, highlighting the importance of collaborative efforts and stakeholder engagement in assembling sustainable practices. Their findings suggest that sustainability initiatives can improve environmental performance and social outcomes when integrated into organisational strategies.

To illustrate how the CRT aligns with UN SDGs, Table 3 provides a brief overview.

By aligning with these specific UN's SDGs, the CRT ensures that the adoption of PA in vineyard management enhances operational efficiency and contributes to broader sustainability goals. This alignment demonstrates the CRT's role in promoting environmentally responsible practices and supporting the global agenda for sustainable development.

Identifying the research gap

Despite recognising the importance of corporate governance, integrated thinking and sustainability, there needs to be a comprehensive and structured approach combining these elements with the implementation of technologies like PA in vineyard management. Existing studies have focussed on individual aspects such as sustainability programmes (Legun & Sautier, 2018; Nazzaro et al., 2022) or governance structures (Spraul & Höfert, 2021; Visser & De Langen, 2006), but have yet to provide an integrated IT governance framework with the use of a template that addresses the risks associated with the implementation of such technologies and still ensuring IT governance (Simonsson & Johnson, 2006), which is being illustrated in Figure 2.

This gap underscores the need for a tool like the CRT, which adopts the COBIT 2019 framework to effectively manage the inherent risks while maintaining high standards of IT governance (ISACA, 2018). We chose the COBIT 2019 framework for its comprehensive and adaptable governance objectives, which are well-suited to the complexities of vineyard management including data integrity, security and the seamless integration of diverse data sources.

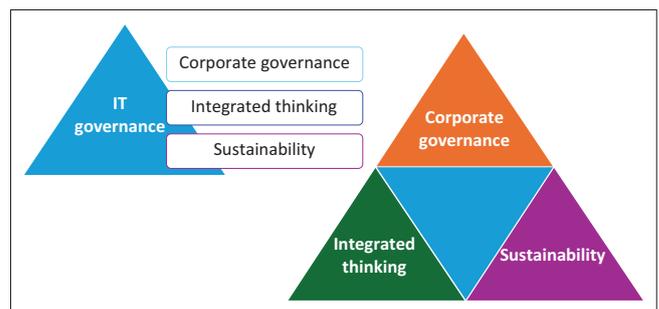
By incorporating the COBIT 2019 objectives, the CRT facilitates a unified template for seamless data flow and comprehensive analysis, thereby enhancing decision-making processes and improving grapevine yield and quality through the interconnected data. Developing the CRT involved identifying the relevant COBIT 2019 objectives within the vineyard management context and embedding these objectives into the CRT accordingly (see Table 4 for details).

By integrating these COBIT 2019 objectives into the CRT, we can establish a robust IT governance framework specifically tailored to the unique challenges of vineyard management. However, to effectively operationalise this framework, it is essential to translate these objectives into actionable components that address the industry's technological and viticultural aspects through the use of our CRT.

This necessitates identifying and defining the four building blocks in the following section that will form the foundation of our CRT's components, as these building blocks are designed to integrate vineyard management practices with the implementation of advanced technologies like PA, while still adhering to the corporate governance, promoting integrated thinking and achieving the sustainability goals.

The building blocks of the Control Risk Template

To develop the CRT components, first of all, we must define the following building blocks that outline the multifaceted aspects of vineyard management and its operations.



IT, information technology.

FIGURE 2: Information technology governance gap.

TABLE 3: Alignment of the control risk template with United Nations' sustainable development goals.

UN's Sustainable Development Goal	Alignment with the CRT
Goal 2: Zero Hunger	The CRT facilitates the implementation of PA in vineyard management, optimising agricultural practices such as irrigation, nutrition and pest management. By improving efficiency and yield, the CRT contributes to sustainable agriculture by ensuring that resources are used effectively to produce high-quality grapes. This alignment supports food security and promotes sustainable agricultural methods that can be replicated in other agriculture sectors, thereby contributing to Goal 2.
Goal 6: Clean Water and Sanitation	The CRT enables precise irrigation scheduling through PA by analysing real-time data on soil moisture, weather forecasts and plant needs. This precision reduces water wastage and prevents over-irrigation, promoting the sustainable management of water resources. By implementing efficient water use practices, vineyard operations align with Goal 6, ensuring that water is conserved and available for other uses, contributing to the overall sustainability of water resources.
Goal 12: Responsible Consumption and Production	The CRT provides data-driven recommendations to help minimise waste and optimise using inputs like fertilisers and pesticides. This leads to reduced environmental impact and more sustainable production patterns. By ensuring that production processes are efficient and resources are used responsibly, the CRT aligns vineyard management practices with Goal 12.

PA, prescriptive analytics; UN, United Nations; CRT, Control Risk Template.

TABLE 4: COBIT 2019 Governance and Management Objective(s).

Objective code and name	How the objectives are embedded within the CRT
BAI06 – Manage Changes	Guides systematic risk control measures tailored for changes in PA systems and vineyard management processes, ensuring that modifications adhere to risk management strategies and contribute to sustainable agricultural practices.
MEA01 – Monitor, Evaluate and Assess Performance and Conformance	It supports CRT's rigorous assessment of operational and IT-related performance in vineyard management enabling enhanced irrigation, nutrition and pest control decision-making, which is crucial for optimising vine growth and production.
MEA02 – Monitor, Evaluate and Assess the System of Internal Control	Ensures CRT measures conform to regulatory and safety standards, align with sustainable agriculture practices and maintain compliance in managing grapevine life cycle risks through prescriptive analytics.
EDM03 – Ensure Risk Optimisation	This is reflected in CRT's approach to proactively identifying, assessing and mitigating IT-related risks, enhancing the reliability of decision-making processes and supporting the advancement of precision agriculture techniques.
APO13 – Manage Security	It ensures robust management of IT security risks within vineyard operations, which protects data integrity and supports the secure implementation of PA as per the COBIT 2019 framework.
APO10 – Manage Suppliers	CRT emphasises effectively managing interconnected risks affecting various vineyard operations including external stakeholder relationships, which are crucial for collaborative and sustainable vineyard management practices.
APO12 – Manage Risk	Central to the CRT's comprehensive risk management strategy, ensuring a holistic approach to identifying, assessing and mitigating risks associated with deploying PA in vineyard management.
APO02 – Manage Strategy	Aligns strategic vineyard management goals with risk management activities within the CRT, ensuring that all operations are strategically oriented to support sustainable agricultural practices and the SDGs.
APO03 – Manage Enterprise Architecture	Integrates IT infrastructure planning with risk management needs within the CRT, facilitating the effective deployment of PA that enhances operational decisions in vineyard management.
BAI01 – Manage Programmes and Projects	Manages the lifecycle and risks associated with implementing and optimising programmes and services in vineyard management, ensuring they align with COBIT standards and sustainable agricultural practices.

CRT, Control Risk Template; PA, prescriptive analytics; IT, information technology; COBIT, Control Objectives for Information and Related Technology; SDG, Sustainable Development Goal.

Understanding these aspects is essential before implementing PA, as it provides the necessary context and foundation for integration and implementation of this technology within vineyard management.

The building blocks are:

- Grapevine Life Cycle Stages (GLCS).
- Grapevine Anatomy (GA).
- Data Life Cycle Stages (DLCS).
- Prescriptive Analytical IT Architecture Components (PAIAC).

The rationale for defining these specific building blocks is twofold:

- Understanding the operational environment: To develop a detailed understanding of the vineyard's operational environment elements (GLCS and GA). This understanding is crucial for tailoring PA solutions that are appropriate and effective for each stage of the grapevine's development and its anatomical features.
- Establishing IT risk management strategy: To establish a robust IT risk management strategy that aligns with this understanding (DLCS and PAIAC elements). By mapping out the data lifecycle and IT architecture components, we can identify and mitigate data integrity, security and system integration risks.

By defining these building blocks, we address the research gap identified earlier – the lack of a comprehensive and structured approach to integrating advanced technologies like PA in vineyard management while managing associated risks through a proper IT governance framework with the use of a template. These building blocks are not merely procedural checkpoints but foundational elements that will ensure the optimal use of PA within vineyard management.

Grapevine life cycle stages

A detailed understanding of the GLCS – bud break, flowering, fruit set, veraison, harvest and dormancy – is essential for

tailoring PA effectively within vineyard management (Lorenz et al., 1995). Each stage encapsulates physiological changes and needs, demanding precise and timely management interventions to ensure optimal growth and yield (Barriguinha et al., 2021). Table 5 describes the different GLCS and shows how PA is deployed in the various stages of vineyard management.

As explained in Table 5, the first building block is to align the GLCS with the deployment of PA. This alignment is crucial for maintaining the integrity and effectiveness of vineyard operations, providing a clear roadmap for integrating advanced analytics into everyday agricultural practices. In doing so, management can enhance decision-making by ensuring a cohesive approach to managing each phase's unique challenges. To illustrate how the grapevine life cycle stages, Figure 3 provides an overview of each phase of which is being considered later on within the CRT in the context of vineyard management.

In the proceeding section, we will explore the detailed anatomy of the grapevine. By comprehensively understanding each anatomical component, management can effectively implement PA to achieve optimal growth and production levels. A deep knowledge of the structure and function of the grapevine anatomy enables farmers to tailor each intervention precisely, thereby, improving the overall health and productivity of the vine.

Grapevine anatomy

Understanding the GA is imperative for effectively applying PA throughout the various life cycle stages of the grapevine. As outlined in Table 6, key anatomical components – roots, shoots, leaves, flowers, berries, trunk, tendrils and canopy – play crucial roles in the vine's development and response to environmental conditions (Mullins et al., 1992). By comprehensively defining these components within the CRT, vineyard managers can ensure that interventions are

TABLE 5: Grapevine life cycle stages and prescriptive analytics.

Stage	Description
Bud break	<p>The bud break phase initiates the grapevine's annual life cycle, typically occurring with the onset of stable, warmer temperatures in the spring season (Lorenz et al., 1995). This stage is characterised by the swelling and unfolding of dormant buds, revealing young shoots essential for supporting future leaves and grape clusters (Lorenz et al., 1995). The biological mechanisms at this stage are influenced by cumulative temperature and photoperiod, regulating the enzymatic activities necessary for bud development (Mullins et al., 1992).</p> <p>PA in vineyard management: PA leverages historical and real-time data to forecast the optimal conditions for bud development. Advanced models diligently analyse weather patterns to predict frost risks (Bendre et al., 2015), a potential threat to young buds. Similarly, soil moisture sensors and nutrient profiles are examined to tailor irrigation and fertilisation plans, ensuring vines receive adequate hydration and nutrients without the stress of over- or under-supply (Intrigliolo & Castel, 2009).</p>
Flowering	<p>Following bud break, the grapevine enters the flowering stage around late spring to early summer (Lorenz et al., 1995). During this critical period, the vine develops flower clusters crucial for the fruit set, with each flower having the potential to form a single grape, thus directly influencing the potential yield (Mullins et al., 1992). This phase demands careful surveillance to foster an environment conducive to self-pollination, a prevalent method in grapevines (Lorenz et al., 1995). Adequate pollination during this stage is sensitive to environmental conditions including temperature, humidity and wind which can affect the pollen's viability and success of the pollination process (Mullins et al., 1992).</p> <p>PA in vineyard management: Advanced data models utilise real-time and historical climate data to forecast weather conditions that might impact flowering such as sudden temperature drops or excessive rainfall (Bendre et al., 2015). These models help vineyard managers make pre-emptive decisions to mitigate risks. For instance, if a risk of frost is predicted, protective measures such as frost fans or water sprinklers can be activated to safeguard the delicate flowers (Petrović et al., 2024). Similarly, predictive models analyse soil moisture data to adjust irrigation systems, ensuring that the vines are neither water-stressed nor over-irrigated during this sensitive phase. Nutrient management is also fine-tuned based on predictive insights, optimising the timing and composition of fertiliser applications to support optimal floral development and health (Coombe, 1995).</p>
Fruit set	<p>After the flowering stage, the vineyard progresses into the fruit set phase, where pollinated flowers transform into diminutive green berries, marking a critical juncture in the development of the grapevine (Lorenz et al., 1995). During this stage, the initial formation of the grape berries occurs and the vineyard managers can start to gauge the potential harvest yield based on the rate of successful fertilisation and the subsequent growth of these berries (Mullins et al., 1992). This phase is sensitive to environmental conditions, as extreme weather can affect berry development and reduce the overall fruit set (Coombe, 1995).</p> <p>PA in vineyard management: PA analyses data from sensors and historical weather patterns, and prescriptive models can predict potential threats to the crop such as sudden temperature changes or excessive rainfall (Sishodia et al., 2020). Based on these forecasts, vineyard managers can take preventive measures to ensure optimal growing conditions such as adjusting the microclimate around the vines or modifying irrigation schedules (Intrigliolo & Castel, 2009). Additionally, PA can help precisely apply essential nutrients during this growth phase ensuring that the young berries receive the necessary resources to develop fully (Coombe, 1995).</p>
Veraison (ripening)	<p>The veraison stage inaugurates the grape ripening process, unfolding mid to late summer (Lorenz et al., 1995). During this pivotal stage, grapes undergo significant physiological changes including a shift in colour from green to red or yellow, depending on the variety, and the gradual accumulation of sugars, acids and phenolic compounds essential for flavour and aroma development (Santesteban & Royo, 2006). This stage marks a critical transition from grape growth to maturation, requiring precise management to ensure optimal fruit quality (Lorenz et al., 1995).</p> <p>PA in vineyard management: By analysing real-time data from weather stations and soil sensors (Bendre et al., 2015), vineyard managers can adjust irrigation systems to provide the proper moisture levels and adjust nutrient management to support sugar accumulation and colour development in the berries (Intrigliolo & Castel, 2009). PA can also guide the timing and type of pest and disease management interventions, ensuring minimal impact on the grapes nearing harvest (Coombe, 1995).</p>
Harvest	<p>The harvest stage marks the culmination of the grapevine's growth cycle, focussing on assessing the grapes' readiness for harvest (Lorenz et al., 1995). This critical phase involves a meticulous analysis of the grapes' biochemical makeup – including sugar levels, acidity and phenolic compounds – to determine the optimal timing for harvest, which is essential for achieving the desired wine quality (Santesteban & Royo, 2006). The evaluation also considers prevailing environmental conditions, which can influence the final stages of maturation (Coombe, 1995).</p> <p>PA in vineyard management: By integrating real-time data from sensors monitoring climate conditions, soil moisture and grape maturity indicators alongside predictive models, PA aids in determining the best strategies for post-harvest handling and initial winemaking steps (Petrović et al., 2024).</p>
Dormancy	<p>Post-harvest, the grapevine transitions into the dormancy stage characterised by a period of biological inactivity as the plant conserves energy for the next growth cycle (Lorenz et al., 1995). During this stage, the vine sheds its leaves, revealing the bare stems, which are then subjected to essential maintenance processes such as pruning (Mullins et al., 1992). This phase is crucial for resting the vine and preparing it for the subsequent bud break stage, making vineyard management decisions particularly pivotal (Lorenz et al., 1995).</p> <p>PA in vineyard management: Using data-driven models, managers can analyse soil health and prescribe specific soil amendments or cover cropping strategies that enhance soil structure and fertility (Coombe, 1995). Additionally, PA aids in optimising the timing and techniques of pruning, supporting efficient energy conservation in the vines and better bud development in the spring (Coombe, 1995).</p>

Note: Please see the full reference list of this article <https://doi.org/10.4102/sajbm.v55i1.4708> for more information.

PA, prescriptive analytics.

accurately tailored to meet the physiological requirements and challenges at each stage – from bud breakthrough to dormancy, as outlined in Table 6.

As explained in Table 6, the second building block is aligning the deployment of PA with the GA. In doing so, management can enhance the decision-making process by simultaneously ensuring a cohesive approach to managing the unique challenges over each life cycle stages and anatomical components with the implementation of PA on their farm. The first two building blocks are essential to ensure that the GLCS and GA are well integrated into the third building block, namely, the DLCS, setting the stage for effectively deploying PA within vineyard management.

To illustrate grapevine anatomy, Figure 4 provides an overview of each anatomical component that will be

considered later within the CRT in the context of vineyard management.

Data life cycle stages

Defining the data lifecycle in the context of grapevine management will provide grapevine managers with detailed insights into each growth phase and structural component of the grapevine. These insights will influence the entire data lifecycle process – from collection, storage and pre-processing to analysis, application, decision-making, reporting and retention. A comprehensive understanding will ensure that PA can be precisely implemented to meet the specific needs of the vine at every stage of its life cycle and for each anatomical part. Table 7 describes the DLCS in the context of vineyard management.

As outlined in Table 7, the third building block involves aligning the DLCS with the GLCS and GA. By achieving this

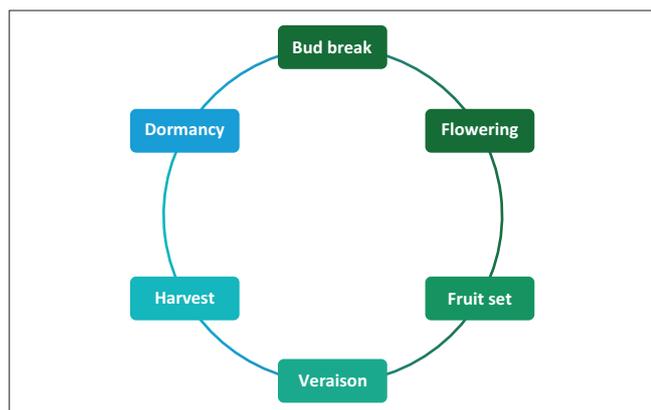


FIGURE 3: Grapevine life cycle stages.

alignment, management can improve the decision-making process through a unified approach to handling the distinct implementation challenges of each stage of the data life cycle. To fully harness the benefits of this strategic alignment, defining the IT architecture components, as elaborated in the preceding section, is crucial as it forms part of our final building block to develop the CRT and effectively identify, assess, and manage the risks of deploying PA in vineyard management.

To illustrate DLCS, Figure 5 provides an overview of each phase that will be considered later within the CRT in the context of vineyard management.

Prescriptive analytical information technology architecture components

A comprehensive understanding of the grapevine's life cycle and anatomical structure is essential. However, this knowledge attains its full utility only when integrated with the overarching IT architecture components that underpin the data life cycle. The different PAIACs, namely the data layer, data processing layer, analytical layer, decision layer and presentation layer, require an understanding to enable management with the successful implementation of PA in vineyard management with precision in every DLCS – from data collection to retention – as delineated in Table 8.

As outlined in Table 8, the final building block involves aligning the PAIAC with the DLCS. This alignment can improve the decision-making process by using a unified approach to handling the distinct implementation challenges of each phase of the GLCS and GA.

To illustrate PAIAC, Figure 6 provides an overview of each layer that will be considered later within the CRT in the context of vineyard management.

By defining and understanding the four key building blocks – GLCS, GA, DLCS and PAIAC – we have formed the foundational elements of our CRT, providing a structured framework that integrates vineyard management practices with the implementation of advanced technologies like PA, while aligning it with the corporate governance principles, promoting integrated thinking and achieving the sustainability goals.

However, the research aims to develop a CRT that incorporates the COBIT 2019 objectives to effectively manage IT-related risks with the implementation of such technologies within vineyard management. The next section therefore, will detail the methodology we have employed before proceeding to our findings on how the CRT is developed based on our systematic literature review.

Methodology

This research explores how the COBIT 2019 framework can be integrated into vineyard management to optimise irrigation, nutrition and pest management decision-making. Through developing a CRT, the study bridges the gap between IT governance frameworks and the operational needs of vineyard management; leveraging PA to meet the SDGs related to sustainable agriculture and water management.

The study adopts an exploratory research design. This approach is suitable for creating a comprehensive template that meets the unique requirements of vineyard management and aligns with global IT governance standards. A Grounded Theory (GT) methodology underpins the research, which is ideal for areas lacking pre-established theories (Sutton et al., 2011). This methodology facilitates the development of a theoretical template that supports integrating the COBIT framework within the context of agricultural technology, specifically vineyard management. This systematic and inductive approach is essential to derive insights into effective data-driven methodologies that enhance vineyard productivity and sustainability.

While we considered employing a systematic literature review approach based on one of Grant and Booth's (2009) comprehensive typology of 14 review types, we found Wolfswinkel et al.'s (2013) structured five-stage literature review process to be more appropriate for our study's focus on IT governance in vineyard management. This method is particularly suited to information systems research and provides a rigorous framework that includes defining the scope, conducting literature searches, selecting relevant literature, analysing the content and systematically presenting the findings. Each stage is designed to deepen the understanding of how IT governance can be effectively applied in agricultural settings. The different stages of the GT literature review method were executed as follows:

Stage 1: Define

The research domain is within sustainable agriculture, emphasising vineyard management, reflecting the United Nations' emphasis on SDGs. The primary research trajectory intersects the COBIT Governance and Management Objective(s) with vineyard management practices. Initial probes were based on existing literature concerning the applicability of the COBIT framework in agriculture. Given

TABLE 6: The grapevine anatomy and prescriptive analytics.

Component	Description
Roots	<p>The grapevine's root system serves as a critical anchor for the plant, securing it firmly within the soil while also being pivotal in absorbing water and essential nutrients (Lorenz et al., 1995). It features a deep-reaching and complex network that facilitates the uptake of minerals and water, which are indispensable for the plant's growth and development (Lorenz et al., 1995). Moreover, the roots maintain vital physiological processes and adapt the vine to various soil conditions ensuring its sustainability (Mullins et al., 1992).</p> <p>PA in vineyard management: In conjunction with climatic data, predictive models can prescribe specific irrigation schedules and soil amendments to enhance root development and function by analysing soil properties, such as texture, pH, moisture levels and nutrient content (Barriguinha et al., 2021). This approach ensures that the roots receive an optimal balance of water and nutrients, which is crucial for their function and the overall health of the vine. Moreover, PA can guide targeted interventions to mitigate soil-borne diseases and pests that threaten root health. By monitoring and adjusting the microenvironment around the roots, analytics can prevent issues such as waterlogging or drought stress which can severely impair root function and vine vitality (Keller, 2010).</p>
Leaves	<p>The grapevine leaves are crucial for photosynthesis, the process by which the plant converts carbon dioxide and sunlight into glucose, providing the energy necessary for growth and development (Lorenz et al., 1995). In addition to their primary role in energy production, leaves are also involved in transpiration which helps in nutrient uptake and regulates the plant's water content, thereby contributing to the grapevine's overall physiological well-being (Lorenz et al., 1995). The structure and orientation of the leaves significantly influence the microclimate around the grape clusters, affecting both fruit quality and plant health (Mullins et al., 1992).</p> <p>PA in vineyard management: Advanced PA modelling integrating satellite imagery and sensor data can assess leaf density, health and distribution to guide precise pruning and canopy management decisions (Barriguinha et al., 2021). This approach ensures optimal sunlight exposure and air circulation, essential for healthy photosynthesis and reducing the risk of fungal diseases (Lorenz et al., 1995). PA can also aid in determining the optimal timing and quantity of water and nutrients based on the leaves' health and transpiration rates (Petrović et al., 2024).</p>
Shoots	<p>Shoots comprise the new growth on a grapevine that develops from buds on the trunk or older branches (Lorenz et al., 1995). These structures are pivotal as they house the leaves, flowers and fruit, playing a central role in the vine's productivity and fruit quality. Monitoring and managing shoot growth in vineyard management is crucial for regulating yield quality and quantity (Barriguinha et al., 2021). This involves manipulating various viticultural practices, such as pruning and canopy management, to ensure optimal light exposure and air circulation, which is essential for healthy growth and development (Mullins et al., 1992).</p> <p>PA in vineyard management: PA can optimise shoot growth and development by providing actionable insights to vineyard managers through data-driven models (Petrović et al., 2024). These models analyse data from climate sensors, satellite imagery and ground-level observations to determine the best timing and techniques for pruning and training shoots (Barriguinha et al., 2021). By carefully manipulating vine structure, vineyard managers can enhance light penetration and reduce shading within the canopy, essential for maximising photosynthesis (Mullins et al., 1992). PA can also forecast growth patterns and environmental stressors, allowing for specific interventions to protect young shoots and ensure their proper development (Barriguinha et al., 2021). The strategic application of nutrients and water, guided by predictive insights into soil moisture levels and nutrient requirements, ensures that shoots receive the precise support they need during critical growth phases (Mullins et al., 1992). Additionally, analytics-driven pest management strategies can help protect shoots from diseases and pests, severely impacting their health and the quality of the fruit (Barzman et al., 2015).</p>
Flowers and berries	<p>The flowers and berries are the reproductive components of the grapevine, vital for its propagation and fruit production (Mullins et al., 1992). Initially, the vine produces small, inconspicuous flowers which develop into berries after successful pollination during the flowering and fruit set stages. These berries, which eventually mature into grapes, are crucial as they contain the seeds for future plants and are the primary source of grape products such as wine and raisins (Coombe, 1995).</p> <p>PA in vineyard management: PA provides valuable insights that can guide management on caring for and treating flowers and berries to enhance fruit quality and maximise yield (Petrović et al., 2024). By integrating sensor data and predictive modelling, vineyard managers can monitor microclimatic conditions directly affecting flowering and fruit stages (Nuske et al., 2014). Additionally, PA assists in determining the optimal harvest time by continuously monitoring berry maturation and analysing sugar content, acidity levels and phenolic maturity (Santesteban & Royo, 2006).</p>
Trunk	<p>The trunk forms the central structure of the grapevine, providing crucial support to the branches, leaves and fruit (Mullins et al., 1992). It acts as the primary conduit for water and nutrients absorbed through the root system, facilitating their transfer to other plant parts (Mullins et al., 1992). Over time, the trunk thickens and becomes more lignified, offering increased resistance to environmental stress factors. This structural fortification is essential for the long-term viability and productivity of the grapevine, serving as a critical indicator of the overall health and stability of the plant (Mullins et al., 1992).</p> <p>PA in vineyard management: By employing advanced sensor technologies and data analysis (Adamchuk et al., 2004), vineyard managers can monitor the trunk's condition in real-time, detecting early signs of diseases, pests or structural weaknesses that could compromise the vine's viability (Barriguinha et al., 2021). Moreover, during the pruning season, analytics can guide decisions on how to shape the vine to distribute weight evenly across the trunk, preventing structural strain and enhancing the plant's overall architecture (Mullins et al., 1992).</p>
Tendrils	<p>Tendrils are slender, twining stems that play a crucial role in supporting the grapevine by coiling around suitable structures. They facilitate upward growth and secure the plant in a position that maximises sunlight exposure, vital for effective photosynthesis (Mullins et al., 1992). The functionality of tendrils is integral to the grapevine's ability to climb and expand its reach, which is essential for maintaining health and vigour (Lorenz et al., 1995).</p> <p>PA in vineyard management: PA can prescribe the most effective trellising configurations that enhance tendril functionality and vine stability by integrating detailed phenotypic data on tendril development and environmental factors, such as wind patterns and sunlight exposure (Petrović et al., 2024). This includes determining the optimal spacing, orientation and materials for trellis structures to ensure adequate support without inhibiting tendril movement or growth (Barriguinha et al., 2021).</p>
Canopy	<p>The canopy refers to the collective structure formed by the grapevine's shoots, leaves and fruit clusters (Coombe, 1995). It is crucial to the plant's photosynthetic productivity and overall health (Mullins et al., 1992). Proper canopy management, which involves pruning and training, is essential for ensuring adequate air circulation and sunlight penetration, both vital for preventing disease and promoting optimal fruit development (Lorenz et al., 1995).</p> <p>PA in vineyard management: PA is crucial in vineyard management, particularly for optimising canopy management to boost grapevine health and productivity. By utilising data from satellite imagery, climate sensors and historical growth records, advanced analytical models provide detailed insights into factors like canopy density and leaf area index (Barriguinha et al., 2021). Additionally, analytics help adjust training systems for optimal sunlight exposure, crucial for photosynthesis and preventing fungal infections (Mullins et al., 1992).</p>

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PA, prescriptive analytics.

the prominence of PA in vineyard management, the scope was extended to assimilate insights from this analytical realm.

The research relied on comprehensive database searches in Scopus, EBSCOhost and IEEE. Keywords such as 'Prescriptive Analytics', 'COBIT', 'Control Risk Template', 'Vineyard Management', 'Optimisation', 'IT Governance', and 'Precision agriculture' were employed to guide the search. Given the sparse

academic literature intersecting IT governance and vineyard management, supplementary searches encompassed platforms that provide vineyard management software solutions.

This stage's pivotal component was identifying gaps and challenges in contemporary literature related to vineyard management and COBIT. The focus was primarily on vineyard management literature, but a broader perspective was obtained by incorporating insights from the expansive

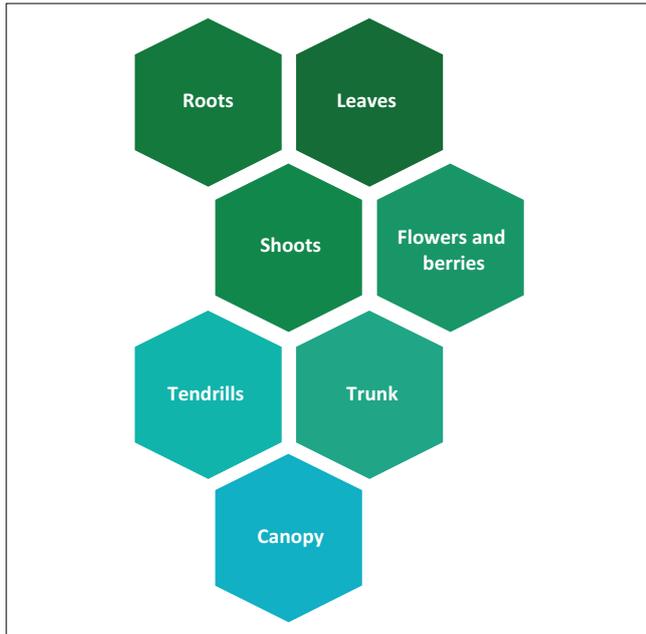


FIGURE 4: Grapevine anatomy.

information systems literature, primarily through the IEEE Xplore database. Keywords associated with COBIT Governance and Management Objective(s) like 'challenges', 'gaps', and 'implementation' were integrated to ensure a thorough search.

Stage 2: Search

Having prepared the criteria and selected the appropriate sources and search terms, the searches were performed systematically. The researchers ensured that essential synonyms of search terms were included if identified.

Stage 3: Select

The literature abstracts identified in the search were read to determine if they were relevant to the study's aim. The search criteria had to be refined in certain instances to find appropriate literature. Those articles that were then found to be in line with the objective of this research were downloaded for analysis.

Stage 4: Analyse

The analytical procedure involved carefully examining vineyard management, striving to pinpoint intersections with the COBIT framework. The aim was to ascertain areas within vineyard operations where governance and management objectives could be seamlessly integrated. Each vineyard management task underwent a systematic breakdown to comprehend inherent challenges and the potential contributions of PA.

The literature was examined to identify specific vineyard management tasks that the COBIT framework could augment. This examination revealed potential integration points, challenges and areas of synergy. The subsequent step involved detailed scrutiny of challenges encountered while integrating

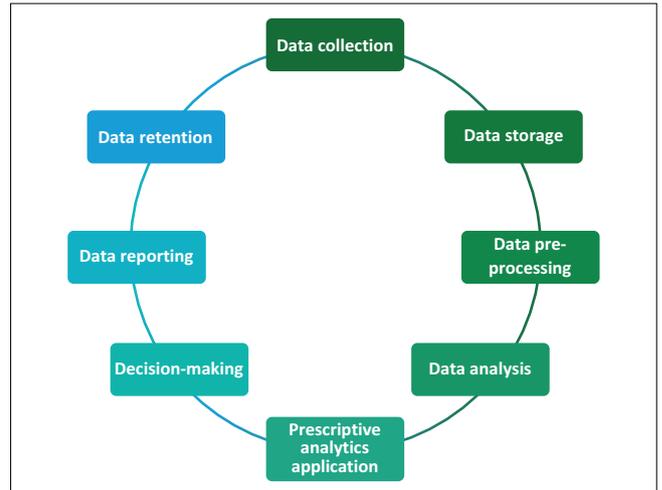


FIGURE 5: Data life cycle stages.

the COBIT framework into vineyard management protocols. These challenges were then contextualised within the broader framework of sustainable agriculture to understand their broader implications. One significant area of analysis revolved around the functionality of the CRT. The aim was to discern its potential role in aligning the COBIT framework with the multifaceted realm of vineyard management, especially in irrigation, nutrition and pest management.

Derived from the analytical process, the findings and insights were consolidated, framing the research's contributions to the broader discourse on sustainable agriculture, vineyard management and IT governance.

Stage 5: Presentation

The last stage of the GT literature review method is to present the findings and insights gained in a structured manner. The analysis and findings are linked and presented according to the research question of this article.

Ethical considerations

Ethical approval to conduct this study was obtained from the University of Stellenbosch Research Ethics Committee: Social, Behavioural and Education Research (No. ACC-2023-27838).

Findings

Our comprehensive literature review revealed a significant gap in the existing body of research: there is a lack of a comprehensive and structured approach that integrates corporate governance principles, integrated thinking and sustainability goals with the implementation of advanced technologies like PA within vineyard management. While individual studies have addressed aspects such as sustainability programmes (Legun & Sautier, 2018; Nazzaro et al., 2022) or governance structures (Spraul & Höfert, 2021; Visser & De Langen, 2006), none have provided an integrated IT governance framework – through the use of a template –

TABLE 7: Data life cycle stage(s) in the context of vineyard management.

Stage	Description
Data collection	In this initial stage of the data life cycle, data pertinent to vineyard management is meticulously gathered, considering various factors such as climatic conditions, soil properties and vine anatomical metrics (Sgroi, 2023). The process leverages modern technologies such as sensors, drones and satellite imaging to acquire precise and extensive data (Sishodia et al., 2020).
Data storage	Following data collection, this phase involves securely storing the amassed data in structured databases (Koot et al., 2021). The data storage stage necessitates robust solutions that accommodate large datasets while ensuring data integrity and facilitating easy retrieval for further processing and analysis (Koot et al., 2021).
Data Pre-processing	Before analysis, the stored data undergoes pre-processing to remove inconsistencies, handle missing values and streamline the dataset for practical research (Koot et al., 2021). This stage is essential in refining the data and rendering it suitable for yielding accurate insights in the forthcoming analytical processes. It involves using sophisticated algorithms to refine the data, enhancing its reliability for analytic procedures (Lepenioti et al., 2020). The pre-processing tasks include normalisation, scaling, feature extraction and transformation techniques designed to optimise the dataset for complex analyses (Lepenioti et al., 2020).
Data analysis	At this juncture, the pre-processed data is subjected to rigorous analysis leveraging advanced analytical tools and methodologies (Lepenioti et al., 2020). This stage involves applying various analytical techniques such as statistical modelling, machine learning algorithms and data visualisation tools to decipher patterns, trends and pertinent correlations crucial for informed decision-making in vineyard management (Palacios et al., 2022).
Prescriptive analytics application	This stage employs computational models and machine learning algorithms to predict potential outcomes and prescribe viable solutions grounded in data-derived insights (Palacios et al., 2022), thus facilitating forward-thinking vineyard management strategies. The application of PA involves using sophisticated decision-making tools that not only suggest actions but also forecast the results of these actions under various scenarios (Lepenioti et al., 2020). These tools utilise historical data, real-time data inputs and predictive models to offer recommendations tailored to improve the vineyard's overall productivity and sustainability (Nuske et al., 2014).
Decision-making	Here, vineyard managers leverage the recommendations and predictions from PA to make informed decisions. Strategies involving pest control, irrigation, nutrient management and other vital aspects of vineyard management are formulated at this stage. The decision-making process ensures that the findings from analytics align with enhancing productivity while maintaining sustainability (Bibri, 2018). This critical phase involves choosing actions likely to produce the best outcomes and considering how these decisions fit broader operational and environmental objectives (Palacios et al., 2022).
Data reporting	This stage encompasses the systematic compilation and presentation of the data insights and the strategies developed to facilitate transparency and informed collaborative decision-making processes (Lepenioti et al., 2020). Detailed reports, including analytical insights and prescribed strategies, are formulated, offering a comprehensive overview of the current state and the envisioned pathway for vineyard management.
Data retention	In the final stage of the data life cycle, crucial data and reports are retained for future reference and regulatory compliance (Lepenioti et al., 2020). This stage involves the strategic preservation of data, guided by policies that dictate the duration of data retention. It ensures a repository for future analytical endeavours and sustains a record of the viticulture evolution grounded in empirical analysis (Lepenioti et al., 2020).

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PA, prescriptive analytics.

TABLE 8: The Prescriptive Analytical information technology Architecture Components and vineyard management.

Component	Description
Data layer	The data layer is a fundamental component of vineyard management's IT architecture, aligning with the 'data collection' and 'data storage' stages outlined in Table 7. It gathers vital data points from various sources, such as environmental sensors, soil moisture probes and drone imagery (Sgroi, 2023). Once collected, this data is securely stored to maintain its integrity and availability for future use (Koot et al., 2021). The data layer leverages advanced database and storage solutions, including on-premises relational databases and cloud storage systems, to ensure a structured and scalable repository of vineyard data (Tascione et al., 2024). This structured repository facilitates efficient data management and retrieval, essential for subsequent analytical processes driving vineyard operations (Akhter & Sofi, 2022). The robustness of this layer is crucial, supporting day-to-day decisions, long-term strategic planning and regulatory compliance (Rodrigues, 2022).
Data processing layer	The data processing layer, aligned with the 'data pre-processing' stage in Table 7, is crucial for refining data before analysis (Akhter & Sofi, 2022). This layer applies algorithms to remove inconsistencies and fill in missing values, creating a reliable dataset for analysis (Lepenioti et al., 2020). Essential procedures like normalisation, error correction, feature extraction and dimensionality reduction ensure the data's accuracy and consistency, accurately reflecting vineyard conditions and preparing it for advanced analytics (Akhter & Sofi, 2022).
Analytics layer	The Analytics Layer, corresponding to 'data analysis' and 'prescriptive analytics application' from Table 7, is the core for in-depth analysis (Palacios et al., 2022). It uses computational models and advanced tools to decode patterns and identify trends in the dataset (Akhter & Sofi, 2022). This layer applies machine learning algorithms and statistical models for predictions and prescriptive insights crucial for strategic vineyard management (Lepenioti et al., 2020). Techniques like predictive modelling, cluster analysis, regression analysis and pattern recognition extract actionable insights, enhance decision-making in crop health monitoring, yield prediction and resource allocation (Akhter & Sofi, 2022).
Decision layer	Aligned with the 'decision-making' stage in Table 7, the Decision Layer uses analytical insights to guide vineyard managers in crafting data-driven strategies (Lepenioti et al., 2020). This layer turns analysis into actionable pest control, irrigation and nutrient management decisions. It includes tools and platforms for interpreting insights and ensuring decisions are based on comprehensive data analysis (Koot et al., 2021). Decision support systems and advanced technologies streamline this process, enabling timely, informed responses to vineyard challenges and opportunities (Akhter & Sofi, 2022).
Presentation layer	The Presentation Layer mirrors the 'data reporting' stage in Table 7 and is central to the holistic visualisation and structured representation of analytical outcomes and devised strategies (Lepenioti et al., 2020). This layer is equipped with tools for systematic compilation, enabling stakeholders to understand the analytical trajectories and strategic pathways in vineyard management through detailed reports. It utilises advanced visualisation tools to present data in an intuitive and accessible format (Karaman et al., 2023), facilitating the clear communication of complex information to all levels of vineyard management and stakeholders. This layer displays historical data and real-time analytics and integrates predictive insights and prescriptive recommendations into operational workflows (Karaman et al., 2023).

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IT, information technology.

that addresses the risks associated with implementing of such advanced technologies like PA while ensuring alignment with corporate governance, integrated thinking and sustainability goals.

This gap underscores the need for a template like the CRT, which incorporates the COBIT 2019 framework objectives to manage inherent risks with the implementation of such technologies like PA while maintaining high standards of IT governance practices as existing guidelines for alignment between business and IT are still insufficient (Simonsson &

Johnson, 2006). This will ensure the business objectives being aligned with the IT governance processes and objectives as well (Boshoff, 2007).

The gap between business and IT is referred to as the IT gap for purposes of this study (Goosen & Rudman, 2013; Smit, 2009). Both business and IT managers acknowledge the existence of this infamous gap in alignment between their respective sectors (Rudman, 2008), as illustrated in Figure 7, and when the IT gap is eliminated, will result in the alignment (Boshoff, 2007).

This brought about the creation of the Control Risk Triangle concept based on the identified gap, which illustrates the interconnected relationship between corporate governance, IT governance, sustainability and integrated thinking (see Figure 8). This model can provide effective risk management in vineyard management, particularly with the implementation of PA, which requires a balance between these components with the appropriate IT governance framework in place (Rudman, 2008).

To illustrate the CRT, Table 9 provides an overview of each phase and component of the CRT which derives from our Control Risk Triangle. This template plays a critical role in integrating diverse, previously isolated data resources (i.e. irrigation, nutrition and pest management) into operational decisions in vineyard management. By addressing the IT-related risks with the implementation of advanced technologies like PA, we can ensure optimal grapevine growth and production levels are obtained through the use of such technologies and still maintaining the appropriate IT governance practices before, during and after each implementation phase.

As illustrated in Table 9, the CRT has the following three phases; namely:

Phase 1: Risks: The initial phase focusses on detecting the inherent risks associated without the mitigating controls in place before or during the implementation of the technology within the existing operations and systems on the farm.

Phase 2: Controls: The controls phase addresses the controls that must be in place to mitigate the implementation risks identified earlier and lower the residual risks accordingly.

Phase 3: Monitoring and evaluation: The final phase is a continuous process that involves regular monitoring and evaluation of the controls implemented on the farm to assess their ongoing effectiveness and efficiency.

Addressing each component within each phase of the CRT template in Table 9 step-by-step will ensure a structured

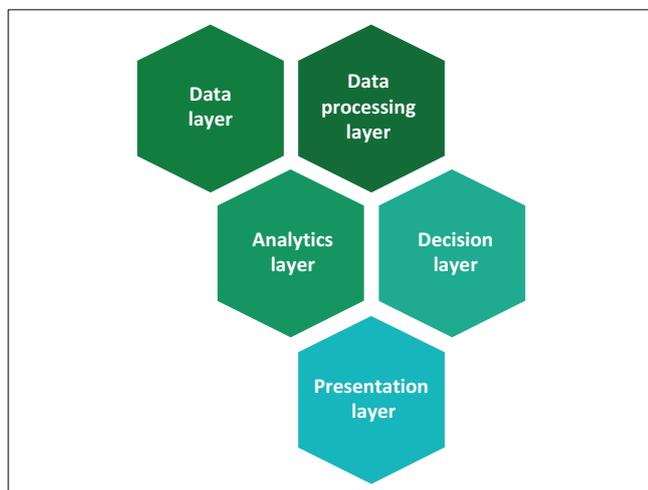
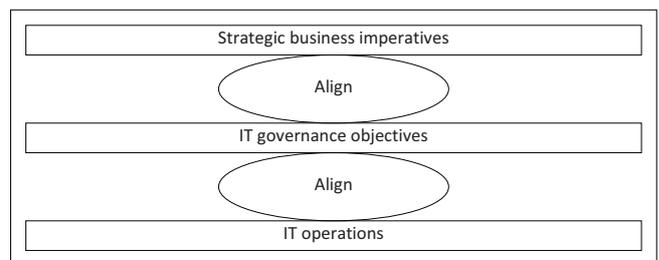


FIGURE 6: Prescriptive analytical information technology architecture components.

approach to managing the complexities and uncertainties inherent with implementing of advanced technologies like PA within vineyard management. This approach will allow us to mitigate the IT-related risks associated with implementing such technologies and ensure it aligns with corporate governance standards, promotes integrated thinking, achieves the sustainability goals and contributes to the organisation's strategic objectives (Adam, 2017).

To effectively convey the CRT's extensive scope in Table 9 regarding each component, we have presented the template in Online Appendix 1. The template is explained in a detailed table covering every component – from initial risk identification to the monitoring and evaluation of control effectiveness. We have also included Figure 9, which provides a comprehensive representation that encapsulates each component of the CRT and offers a holistic view of how each building block we have identified and defined within our literature review integrates within the CRT.

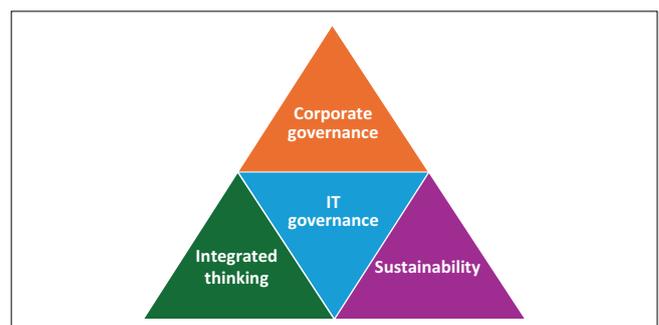
Through the development of the CRT, we have, therefore, effectively addressed the research gap identified in our comprehensive literature review by developing a template which provides a structured approach which can be followed to ensure proper IT governance practices are in place with the implementation of advanced technologies like PA into vineyard management while managing the associated IT-related risks and controls. Future research can, however, delve deeper into the practical application of the CRT, particularly within vineyard management, to determine how successful the use of the template is.



Source: Adapted from Smit, S. (2009). *Defining and reducing the IT gap by means of comprehensive alignment*. Retrieved from https://scholar.sun.ac.za/bitstream/10019.1/15038/1/smit_defining_2009.pdf

IT, information technology.

FIGURE 7: Model for alignment between business and information technology.



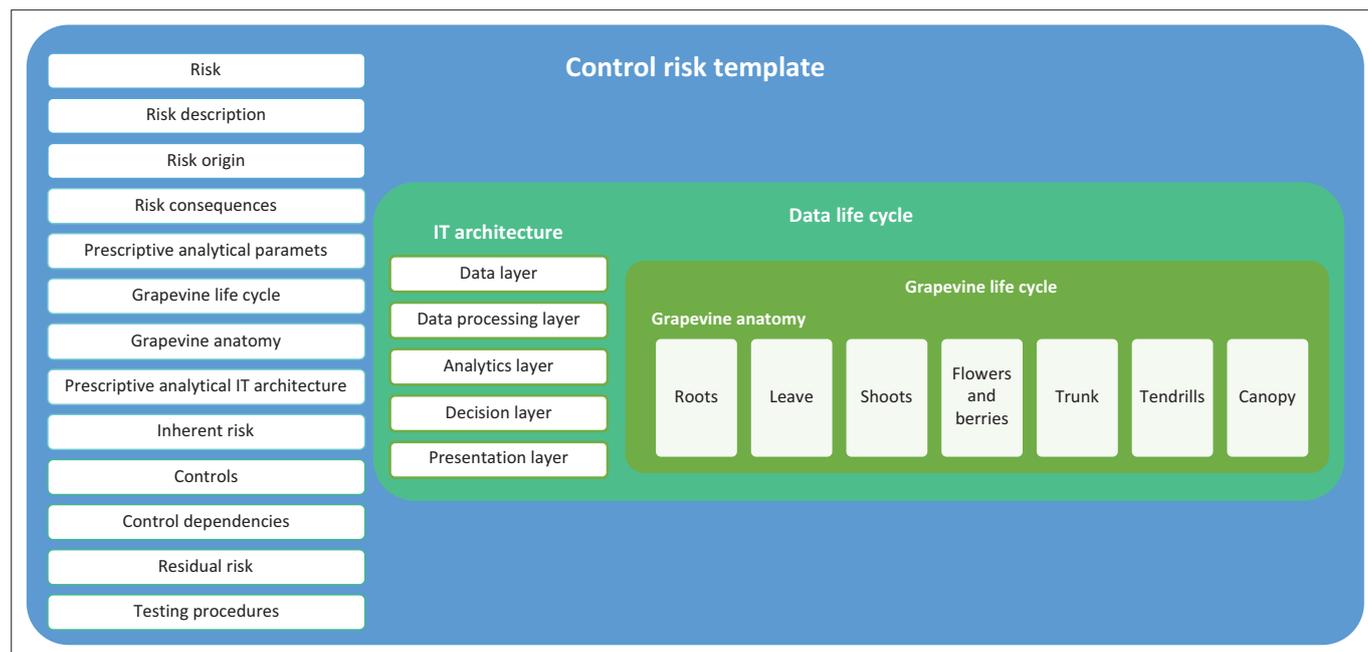
IT, information technology.

FIGURE 8: Control Risk Triangle.

TABLE 9: Components of the control risk template.

Control Risk Template		Phase 1: Risks	Phase 2: Controls	Phase 3: Monitoring and evaluation
Risk	Inherent risk (without controls)	Controls	Residual risk (with controls)	Testing procedures
Risk description				
Risk origin				
Risk consequences				
Prescriptive analytical parameters		Control dependencies		
Grapevine life cycle stage(s)				
Grapevine anatomy				
Prescriptive analytical IT architecture component(s)				

IT, information technology.



IT, information technology.

FIGURE 9: Overview of the Control Risk Template.

Limitations and future research

Several limitations inherent to this research necessitate acknowledgement. The primary focus remains on incorporating the COBIT framework within vineyard management, narrowing the scope to specific irrigation, nutrition and pest management through the CRT. The study does not extend to exploring every objective of the COBIT framework in diverse agricultural settings or various facets of vineyard management.

Reliance on pre-existing literature from a selection of databases poses another limitation, potentially omitting the latest advancements, innovations or real-world applications in the convergence of IT governance and vineyard management. Agricultural practices and information technology's dynamic and swiftly evolving landscapes further accentuate this constraint. Additionally, the study abstains from delving into the operational intricacies or functionalities of individual components of the COBIT framework. Moreover, external environmental variables, industry-specific challenges and other influential factors affecting the implementation and

efficacy of integrating the COBIT framework in vineyard management remain unaddressed.

Recognising these limitations, future research presents a spectrum of possibilities. Successive studies might scrutinise the adaptability and efficacy of the COBIT framework in diverse agricultural environments and management requisites. Empirical research is pivotal to authenticate the proposed framework, examining its real-world application, associated challenges and impacts on outcomes in vineyard management.

Investigations into alternative IT governance frameworks and their applicability in agricultural environments may yield insightful comparisons and contribute to a more diversified and adaptable knowledge base. Assessing the interplay between IT governance and external variables, including environmental conditions, market demands and regulatory prerequisites, could deepen the comprehension of the intricate dynamics in integrating advanced technologies within agriculture.

Given the UN's emphasis on sustainable agriculture, future studies could assess how integrating IT governance

frameworks, such as the COBIT framework, aligns with achieving sustainability objectives within the agricultural sector. Exploring the potential benefits, alongside challenges, of such integration could offer balanced viewpoints, fostering the development of agricultural practices that are both effective and sustainable.

Building on this article's findings, future research could also delve deeper into the practical application of these frameworks, particularly within varied vineyard management contexts. A comparative analysis of traditional and analytics-driven vineyard management approaches could offer insights into tangible benefits and potential pitfalls.

Addressing these limitations and exploring the suggested avenues for future research can contribute to advancing knowledge and practical application of IT governance in agriculture. Such efforts align with broader discourses on sustainability and innovation in agricultural practices, adding significant value to academic and industry realms.

Conclusion

The research focussed on integrating PA into vineyard management through the COBIT framework, emphasising enhancing irrigation, nutrition and pest management decision-making. The CRT serves as a tool to align COBIT's Governance and Management Objective(s) within vineyard management, emphasising the GLCS, GA, DLCS and PAIAC.

The study prominently addressed the governance of varied data streams in viticulture. The COBIT framework emerged as an instrumental risk management solution, seamlessly integrating these data sources to ensure risk mitigation. Traditional practices in vineyard management, rooted in empirical observations, highlighted the existing gap in the use of data-driven methodologies. The study's proposed framework fills this gap, suggesting an enhanced integration of PA in vineyard management.

A significant research finding was the lack of data-driven methodologies in current vineyard management practices. The study revealed the potential benefits of the COBIT framework in this context, offering a fresh perspective on conventional decision-making processes by furnishing actionable insights and management implications. By merging academic literature with real-world applications, the study provides insights that can benefit academic and industry stakeholders.

The study is relevant considering the UN's emphasis on sustainable agriculture. Integrating IT governance principles into vineyard management presents an approach that aligns with global sustainability goals, offering a model that other agricultural sectors might consider adopting.

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W.A.S. and C.L. conceptualised the article. W.A.S. wrote the initial draft and C.L. reviewed and edited the article before submission.

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Data availability

The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary materials.

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References

- Adamchuk, V.I., Hummel, J.W., Morgan, M.T., & Upadhyaya, S.K. (2004). On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture*, 44(1), 71–91. <https://doi.org/10.1016/j.compag.2004.03.002>
- Adams, C.A. (2017). Conceptualising the contemporary corporate value creation process. *Accounting Auditing & Accountability Journal*, 30(4), 906–931. <https://doi.org/10.1108/aaaaj-04-2016-2529>
- Akhter, R., & Sofi, S.A. (2022). Precision agriculture using IoT data analytics and machine learning. *Journal of King Saud University – Computer and Information Sciences*, 34(8), 5602–5618. <https://doi.org/10.1016/j.jksuci.2021.05.013>
- Anderson, K & Pinilla, V. (2018). *Wine globalization: A new comparative history*. Cambridge University Press.
- Bansal, S., Parker, C., & Kazaz, B. (2021). Business analytics in agriculture: Emerging practice and research issues. June 5, 2021. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3860913>
- Barriguinha, A., De Castro Neto, M., & Gil, A. (2021). Vineyard yield estimation, prediction, and forecasting: A systematic literature review. *Agronomy*, 11(9), 1789. <https://doi.org/10.3390/agronomy11091789>
- Barzman, M., Bärberi, P., Birch, A.N.E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., Hommel, B., Jensen, J.E., Kiss, J., Kudsk, P., Lamichhane, J.R., Messéan, A., Moonen, A.-C., Ratnadass, A., Ricci, P., Sarah, J.-L., & Sattin, M. (2015). Eight principles of integrated pest management. *Agronomy for Sustainable Development*, 35(4), 1199–1215. <https://doi.org/10.1007/s13593-015-0327-9>
- Bendre, M.R., Thool, R.C., & Thool, V.R. (2015). Big data in precision agriculture: Weather forecasting for future farming. In *2015 1st international conference on Next Generation Computing Technologies (NGCT)*. 04-05 September 2015. IEEE (Institute of Electrical and Electronics Engineers).
- Bibri, S.E. (2018). The IoT for smart, sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability. *Sustainable Cities and Society*, 38, 230–253. <https://doi.org/10.1016/j.scs.2017.12.034>
- Bongiovanni, R., & Lowenberg-DeBoer, J. (2004). Precision agriculture and sustainability. *Precision Agriculture*, 5(4), 359–387. <https://doi.org/10.1023/b:prag.0000040806.39604.a>
- Boshoff, W. (2007). *IT Governance: IT Governance frameworks and their integration*. Masters in Accounting (Computer Auditing) presentation. Stellenbosch University.

- Coombe, B.G. (1995). Growth stages of the grapevine: Adoption of a system for identifying grapevine growth stages. *Australian Journal of Grape and Wine Research*, 1(2), 104–110. <https://doi.org/10.1111/j.1755-0238.1995.tb00086.x>
- Department of Agriculture, Land Reform and Rural Development (DALRRD). (2023). *Annual performance plan 2023–2024*. DALRRD. Retrieved from <https://www.dalrrd.gov.za/images/annual-performance-plans/annual-performance-plan-2023-2024.pdf>
- Dimes, R., & De Villiers, C. (2020). How management control systems enable and constrain integrated thinking. *Meditari Accountancy Research*, 29(4), 851–872. <https://doi.org/10.1108/medar-05-2020-0880>
- Dimes, R., & De Villiers, C. (2024). Hallmarks of integrated thinking. *The British Accounting Review*, 56(1), 101281. <https://doi.org/10.1016/j.bar.2023.101281>
- Goosen, R., & Rudman, R. (2013). An integrated framework to implement it governance principles at a strategic and operational level for medium-to large-sized South African businesses. *International Business & Economics Research Journal (IBER)*, 12(7), 835. <https://doi.org/10.19030/iber.v12i7.7972>
- Grant, M.J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, 26(2), 91–108. <https://doi.org/10.1111/j.1471-1842.2009.00848.x>
- Herath, R., Senaratne, S., & Gunaratne, N. (2021). Integrated thinking, orchestration of the six capitals and value creation. *Meditari Accountancy Research*, 29(4), 873–907. <https://doi.org/10.1108/medar-01-2020-0676>
- INRIA. (2022). *White paper: Agriculture and digital technology*. INRIA. Retrieved from https://www.inria.fr/sites/default/files/2022-02/white-paper-agriculture-digital-technology-2022_INRIA_BD.pdf
- Institute of Directors in Southern Africa. (2016). King IV report on corporate governance for South Africa 2016. Institute of Directors Southern Africa. Retrieved from <https://www.iodsa.co.za/page/king-iv-report>
- International Integrated Reporting Council (IIRC). (2013). *The International <IR> Framework*. International Integrated Reporting Council. Retrieved from <https://integratedreporting.ifrs.org/wp-content/uploads/2015/03/13-12-08-THE-INTERNATIONAL-IR-FRAMEWORK-2-1.pdf>
- Intrigliolo, D.S., & Castel, J.R. (2009). Response of grapevine cv. ‘Tempranillo’ to timing and amount of irrigation: Water relations, vine growth, yield and berry and wine composition. *Irrigation Science*, 28(2), 113–125. <https://doi.org/10.1007/s00271-009-0164-1>
- ISACA. (2018). *COBIT 2019 framework*, Information Systems Audit and Control Association.
- Kamangir, H., Sams, B.S., Dokoozlian, N., Sanchez, L., & Earles, J.M. (2024). Large-scale spatio-temporal yield estimation via deep learning using satellite and management data fusion in vineyards. *Computers and Electronics in Agriculture*, 216, 108439. <https://doi.org/10.1016/j.compag.2023.108439>
- Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F.X. (2017). A review on the practice of big data analysis in agriculture. *Computers and Electronics in Agriculture*, 143, 23–37. <https://doi.org/10.1016/j.compag.2017.09.037>
- Karaman, B., Taskin, S., Simbeye, D.S., Mkiramweni, M.E., & Kurtoglu, A. (2023). Design and development of smart cover system for vineyards. *Smart Agricultural Technology*, 3, 100064. <https://doi.org/10.1016/j.atech.2022.100064>
- Keller, M. (2010). Managing grapevines to optimise fruit development in a challenging environment: A climate change primer for viticulturists. *Australian Journal of Grape and Wine Research*, 16, 56–69. <https://doi.org/10.1111/j.1755-0238.2009.00077.x>
- Koot, M., Mes, M.R.K., & Iacob, M.E. (2021). A systematic literature review of supply chain decision making supported by the Internet of Things and Big Data Analytics. *Computers & Industrial Engineering*, 154, 107076. <https://doi.org/10.1016/j.cie.2020.107076>
- Legun, K., & Sautier, M. (2018). Sustainability programs and deliberative processes: Assembling sustainable winegrowing in New Zealand. *Agriculture and Human Values*, 35(4), 837–852. <https://doi.org/10.1007/s10460-018-9879-z>
- Lepenioti, K., Bousdekis, A., Apostolou, D., & Mentzas, G. (2020). Prescriptive analytics: Literature review and research challenges. *International Journal of Information Management*, 50, 57–70. <https://doi.org/10.1016/j.ijinfomgt.2019.04.003>
- Lorenz, D.H., Eichhorn, K.W., Bleiholder, H., Klose, R., Meier, U., & Weber, E. (1995). Growth Stages of the Grapevine: Phenological growth stages of the grapevine (*Vitis vinifera* L. ssp. *vinifera*) – Codes and descriptions according to the extended BBCH scale. *Australian Journal of Grape and Wine Research*, 1(2), 100–103. <https://doi.org/10.1111/j.1755-0238.1995.tb00085.x>
- Maroun, W., Ecim, D., & Cerbone, D. (2022). Refining integrated thinking. *Sustainability Accounting Management and Policy Journal*, 14(7), 1–25. <https://doi.org/10.1108/sampj-07-2021-0268>
- Mullins, M.G., Bouquet, A., & Williams, L.E. (1992). *Biology of the grapevine*. Cambridge University Press.
- Nazzaro, C., Stanco, M., Uliano, A., Lerro, M., & Marotta, G. (2022). Collective smart innovations and corporate governance models in Italian wine cooperatives: The opportunities of the farm-to-fork strategy. *The International Food and Agribusiness Management Review*, 25(5), 723–736. <https://doi.org/10.22434/ifaamr2021.0149>
- Nuske, S., Wilshusen, K., Achar, S., Yoder, L., Narasimhan, S., & Singh, S. (2014). Automated visual yield estimation in vineyards. *Journal of Field Robotics*, 31(5), 837–860. <https://doi.org/10.1002/rob.21541>
- Palacios, F., Diago, M.P., Melo-Pinto, P., & Tardaguila, J. (2022). Early yield prediction in different grapevine varieties using computer vision and machine learning. *Precision Agriculture*, 24(2), 407–435. <https://doi.org/10.1007/s11119-022-09950-y>
- Petrović, B., Bumbálek, R., Zoubek, T., Kuneš, R., Smutný, L., & Bartoš, P. (2024). Application of precision agriculture technologies in Central Europe-review. *Journal of Agriculture and Food Research*, 15, 101048. <https://doi.org/10.1016/j.jafr.2024.101048>
- Reynolds, A.G. (2022). Viticultural and vineyard management practices and their effects on grape and wine quality. In A.G. Reynolds (Ed.), *Managing wine quality* (pp. 443–539). Woodhead Publishing.
- Rodrigues, G.C. (2022). Precision agriculture: Strategies and technology adoption. *Agriculture*, 12(9), 1474. <https://doi.org/10.3390/agriculture12091474>
- Rudman, R.J. (2008). *IT governance: A new era* (pp. 12–14). Accountancy SA.
- Saïssët, L.A.A., Pavez, I., Temri, L., & Astruc, T. (2023). *Characterising governance, innovations and sustainability in the French wine industry: A comparison between cooperatives and investor-owned firms*. HAL. Retrieved from <https://hal.archives-ouvertes.fr/hal-03684971>
- Sánchez-García, E., Montalvo-Falcón, J.V., Marco-Lajara, B., & Martínez-Falcó, J. (2024). Guiding organizations toward sustainable success: The strategic role of leadership in environmental corporate governance in the wine industry. *Corporate social responsibility and environmental management*, 2024, 1–19. <https://doi.org/10.1002/csr.2925>
- Santesteban, L.G., & Royo, J.B. (2006). Water status, leaf area and fruit load influence on berry weight and sugar accumulation of cv. ‘Tempranillo’ under semiarid conditions. *Scientia Horticulturae*, 109(1), 60–65. <https://doi.org/10.1016/j.scienta.2006.03.003>
- SAWIS (South African Wine Industry Information and Systems). 2023. *South African Wine Industry Statistics No. 48*. SAWIS. Retrieved from <http://www.sawis.co.za>
- Schultz, H.R. (2016). Global climate change, sustainability, and some challenges for grape and wine production. *Journal of Wine Economics*, 11(1), 181–200. <https://doi.org/10.1017/jwe.2015.31>
- Sgroi, F. (2023). Innovation and value creation in agriculture: Results of an experimental analysis of the use of sensors on Sicilian vineyards of chardonnay cultivars. *Smart Agricultural Technology*, 6, 100339. <https://doi.org/10.1016/j.atech.2023.100339>
- Simonsson, M., & Johnson, P. (2006). Assessment of IT governance – A prioritization of cobit. In *Proceedings of the conference on systems engineering: Paper #151*. Retrieved from http://www.ee.kth.se/php/modules/publications/reports/2006/IR-EEICS_2006_007.pdf
- Sishodia, R.P., Ray, R.L., & Singh, S.K. (2020). Applications of remote sensing in precision agriculture: A review. *Remote Sensing*, 12(19), 3136. <https://doi.org/10.3390/rs12193136>
- Smit, S. (2009). *Defining and reducing the IT gap by means of comprehensive alignment*. Retrieved from https://scholar.sun.ac.za/bitstream/10019.1/15038/1/smit_defining_2009.pdf
- Spraul, K., & Höfert, A. (2021). Governance for sustainability: Patterns of regulation and self-regulation in the German Wine Industry. *Sustainability*, 13(6), 3140. <https://doi.org/10.3390/su13063140>
- Statista. (2023). *Global wine industry*. Statista. Retrieved from <https://www.statista.com/topics/7802/global-wine/>
- Sutton, S.G., Reinking, J., & Arnold, V. (2011). On the use of grounded theory as a basis for research on strategic and emerging technologies in accounting. *Journal of Emerging Technologies in Accounting*, 8(1), 45–63. <https://doi.org/10.2308/jeta-10207>
- Tascione, V., Raggi, A., Petti, L., & Manca, G. (2024). Evaluating the environmental impacts of smart vineyards through the Life Cycle Assessment. *Science of The Total Environment*, 922, 171240. <https://doi.org/10.1016/j.scitotenv.2024.171240>
- United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. United Nations. Retrieved from <https://sdgs.un.org/2030agenda>
- Visser, E.-J., & De Langen, P. (2006). The importance and quality of governance in the Chilean wine industry. *GeoJournal*, 65(3), 177–197. <https://doi.org/10.1007/s10708-006-0035-8>
- Wolfswinkel, J.F., Furtmueller, E., & Wilderom, C.P.M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, 22(1), 45–55. <https://doi.org/10.1057/ejis.2011.51>
- Zabawa, L., Kicherer, A., Klingbeil, L., Töpfer, R., Kuhlmann, H., & Roscher, R. (2020). Counting of grapevine berries in images via semantic segmentation using convolutional neural networks. *ISPRS Journal of Photogrammetry and Remote Sensing*, 164, 73–83. <https://doi.org/10.1016/j.isprs.2020.04.0>