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Evaluating Regulatory Frameworks' Impact on Sustainable Building Construction Project Delivery Using AMOS-SEM

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Abstract

The increasing emphasis on sustainable construction has positioned regulatory frameworks as critical drivers of sustainable building construction project delivery (SBCPD), particularly in developing countries such as South Africa. However, the effectiveness of different regulatory instruments remains insufficiently understood. This study investigates the influence of regulatory factors on SBCPD by examining two key constructs: Compulsory Enforcement and Incentivisation (CEI) and the Sustainable Building National Framework (SBNF). A quantitative research design was adopted, and data were analysed using Principal Component Analysis (PCA), Confirmatory Factor Analysis (CFA), and Structural Equation Modelling (SEM) to assess the relationships between regulatory mechanisms and project delivery outcomes. The findings reveal that CEI does not exhibit a statistically significant influence on SBCPD when modelled as a combined construct, despite showing significance when tested independently. This suggests that aggregating compulsory and voluntary regulatory instruments may weaken their explanatory power due to underlying interaction effects. In contrast, SBNF demonstrates a strong and statistically significant positive influence on SBCPD, highlighting the critical role of government-led policies, institutional frameworks, and certification systems in shaping sustainable construction practices. The study contributes to theory by advancing our understanding of regulatory hybridity and the role of institutional drivers in sustainable construction. In practice, the findings underscore the need for coherent, well-articulated policy frameworks, strengthened enforcement capacity, and strategic alignment between voluntary and mandatory instruments. The study concludes that government-led frameworks remain the primary catalyst for sustainable construction delivery in developing economies. These insights provide valuable guidance for policymakers and industry stakeholders seeking to enhance sustainability performance in the built environment.

Keywords: sustainable construction; sustainable building construction project delivery; regulatory frameworks; structural equation modelling; government policy; green building; developing countries; South Africa; institutional theory

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1. Introduction

In developing nations, where rapid urbanisation and population growth continue to exert significant pressure on the built environment, the construction industry (CI) remains a critical driver of socio-economic development, infrastructure provision, and economic growth [1,2]. The CI contributes approximately 6% to global GDP, about 8% in developing economies [3], and nearly 3% in South Africa (SA) [4]. Despite its economic importance,

the industry is also a major contributor to environmental degradation, accounting for substantial energy consumption, greenhouse gas (GHG) emissions, and construction and demolition waste [5]. Globally, the CI consumes between 40% and 50% of raw materials and 40% to 45% of total energy, while generating approximately 30% to 40% of solid waste [6,7]. These environmental pressures are particularly pronounced in Africa, where rapid development is often accompanied by limited infrastructure capacity and weak regulatory enforcement [8,9]. In SA, building construction contributes significantly to environmental challenges, including notable shares of GHG emissions, CO_2 output, and solid waste generation [9,10]. This dual role of the CI as both an economic enabler and an environmental burden positions it at the centre of sustainability discourse.

In response to these challenges, sustainable building construction (SBC) has emerged as a critical approach to balancing economic development with environmental stewardship. SBC refers to the construction of buildings in a manner that minimises environmental impact while achieving social and economic objectives [11]. Beyond environmental considerations, SBC is increasingly recognised as a strategy for improving urban liveability, reducing lifecycle costs, and enhancing long-term economic resilience in developing countries such as SA [12,13].

In response to the social, economic, and environmental issues raised by traditional building methods, sustainable building construction (SBC) has become increasingly important. SBC is "the construction of buildings in a sustainable and green way" [11]. In SBC, buildings are constructed to minimise environmental impact while ensuring the achievement of social and economic objectives [9,14]. In addition to being an environmental necessity, SBC is increasingly viewed in developing countries, such as SA, as a means to enhance urban liveability, reduce lifecycle costs, and foster long-term economic resilience [12,13].

The adoption and effectiveness of SBC practices, however, are strongly influenced by regulatory frameworks. Governments employ a range of instruments, including building codes, standards, and policies, to guide construction activities and align them with sustainability goals [15,16]. From a theoretical perspective, such regulations are designed to establish minimum performance standards, address market failures, and internalise environmental externalities [17]. In practice, however, their effectiveness is shaped by institutional capacity, enforcement mechanisms, and broader socio-economic conditions [18,19]. Empirical evidence indicates that the implementation of SBC-related regulations at the project level remains inconsistent across many developing countries, including those in Africa [20].

In the South African context, despite the presence of relatively advanced regulatory frameworks, including national building regulations, energy efficiency standards, and voluntary green certification systems, SBC adoption remains below optimal levels compared to those in developed economies [10,21]. Persistent challenges include high implementation costs [9,22], limited technical capacity [22,23], weak enforcement [24,25], low market demand [22,26], and fragmented institutional coordination [21]. These constraints highlight a critical disconnect between regulatory intent and practical implementation within the construction sector.

A key factor in determining the success of sustainable building initiatives is the performance of construction project delivery, which is commonly measured in terms of "cost," "time," "quality," and "stakeholder/client satisfaction" [27,28]. Other performance criteria include "health, safety and comfort" [27,29], "environmental objectives" [30], "value for money" [31,32], "end user satisfaction" [31], "construction innovation" [27,33], and "improvement in sustainability rating" [34,35]. Similarly, SBC projects often involve innovative materials, cutting-edge technology, and integrated design processes, which can complicate

projects and require greater stakeholder cooperation [36,37]. Regulations can either mitigate these risks by offering incentives, clarity, and consistency, or they can exacerbate them by overlapping laws, lax enforcement, and a lack of institutional capacity [9,38]. Therefore, assessing how regulations impact the completion of SBC projects is crucial to understanding the effectiveness of sustainability-focused policies.

Although a growing body of research has examined the drivers, barriers, and benefits of SBC in SA and other developing contexts [14,39], limited attention has been given to the performance implications of regulatory frameworks at the project level. Previous studies have primarily focused on identifying regulatory features and assessing stakeholder perceptions, with insufficient emphasis on quantifying their influence on project delivery outcomes. This gap is particularly evident in the absence of studies employing advanced analytical techniques to examine the causal relationships between regulatory constructs and SBC project delivery performance.

Furthermore, existing research has not adequately captured the perspectives of construction professionals operating in key economic regions, such as Gauteng Province, where construction activity is highly concentrated. Given the strategic importance of Gauteng in South Africa's construction landscape, a focused investigation within this context is necessary to generate practically relevant insights.

To address these gaps, this study aims to examine the influence of regulatory frameworks (RF) on sustainable building construction project delivery (SBCPD). To achieve this, the study adopts Structural Equation Modelling (SEM) to test the causal relationships between regulatory constructs and project delivery outcomes. By moving beyond descriptive and factor-based analyses to a causal modelling approach, this research provides a more rigorous and comprehensive understanding of how regulatory mechanisms translate into improved project performance.

This study contributes to both theory and practice by strengthening the empirical linkage between regulatory governance and project delivery in sustainable construction. From a policy perspective, it offers evidence-based insights to enhance the design and implementation of regulatory frameworks in SA. From an industry standpoint, it provides a deeper understanding of how regulatory conditions influence project performance, thereby supporting more effective decision-making. Ultimately, this study contributes to broader efforts to promote sustainable urban development in South Africa and other emerging economies.

2. Literature Review

2.1. SBC Project Delivery (SBCPD) in SA

SBC has emerged as a key strategic objective for transforming the built environment both internationally and in South Africa [10]. The CI is widely recognised as a significant contributor to environmental degradation due to its high energy, water, and raw material consumption, as well as substantial greenhouse gas emissions [6,9]. Consequently, integrating sustainability principles into construction project delivery has emerged as a critical approach to improving the environmental performance of buildings while ensuring economic viability and social well-being [11,40]. In South Africa, the transition toward SBC is increasingly driven by policy frameworks, market demand, environmental pressures, and the need to improve project delivery outcomes across the construction lifecycle [22,23,41].

SBC project delivery refers to the systematic integration of environmental, economic, and social sustainability principles throughout the planning, design, procurement, construction, and operational phases of a building project [42]. This approach seeks to maximise long-term value for stakeholders while minimising the environmental impacts of buildings. To improve building performance and occupant well-being, sustainable buildings typically

incorporate water conservation technologies, energy-efficient systems, eco-friendly materials, and enhanced indoor environmental quality [43]. These characteristics increase asset value and lifecycle cost efficiency while reducing environmental footprints [44].

The successful delivery of sustainable building projects requires integrating sustainability considerations into the early phases of project planning and design [23]. Sustainable project delivery typically involves collaborative decision-making among project stakeholders, including architects, engineers, contractors, and quantity surveyors, to ensure that sustainability objectives are embedded in project design and procurement strategies [37]. Early stakeholder engagement is essential for identifying opportunities for energy efficiency, material optimisation, and lifecycle cost savings [45]. Furthermore, integrated project delivery approaches can improve coordination among project participants and enhance the implementation of sustainable construction strategies [23].

Despite the growing adoption of sustainable building practices, several challenges continue to affect the effective delivery of sustainable construction projects in South Africa. One of the most widely cited barriers is non-compliance with legislation [9,21]. Similarly, there is a perception of high initial capital costs associated with green building technologies and materials [37,46,47]. Although sustainable buildings often provide long-term economic benefits through reduced operational costs and improved asset value, developers may remain hesitant to invest in sustainability features due to short-term financial constraints [48]. Furthermore, limited technical expertise [47], insufficient awareness among industry stakeholders [49], and fragmented policy implementation [21,50] also impede the widespread adoption of sustainable construction practices.

Another significant challenge is integrating sustainability principles into conventional project management processes [23,51]. Traditional construction project delivery models often prioritise cost and time performance over environmental outcomes, thereby limiting the incorporation of sustainability objectives during project execution [52]. Addressing this limitation requires adopting integrated project management frameworks that balance economic, environmental, and social considerations in construction project delivery.

Notwithstanding these challenges, the prospects for SBC in South Africa remain promising. Increasing environmental awareness, rising energy costs, and stronger regulatory requirements are expected to accelerate the adoption of SBC across the CI [9,53]. Furthermore, the growing demand for environmentally responsible buildings among investors, tenants, and government institutions is likely to encourage developers to integrate sustainability into project planning and delivery processes [54].

2.2. Project Delivery Outcomes

This study examines the outcomes of project delivery in relation to SBC regulatory features. According to ref. [35], successful delivery performance is closely associated with the effective execution of SBC. The benefits of this approach encompass timely project completion without delays; cost-effective project delivery devoid of budget overruns; fulfilment of specified quality standards; satisfaction among construction stakeholders and clients; contentment of end-users; assurance of value for money; achievement of environmental objectives; enhancement of health, safety, and comfort; promotion of construction innovation; and improvement in sustainability ratings. Table 1 presents the anticipated project delivery outcomes along with their literature sources.

Table 1. Project delivery outcomes.

Measuring Variables	Sources
Project completion without going beyond the schedule	[28,30,32,55]
Finishing the project without going over budget	[28,30,32]
Fulfilment of the specified quality standards	[28,30,32,55]
Stakeholders/Client Satisfaction	[28,30,32]
End-user satisfaction	[28,30,32]
Value for money	[28,30,32]
Achieved environmental objectives	[30,56]
Health, safety, and comfort	[28,29,33,57]
Construction innovation	[33]
Upgrade in the sustainability rating	[34,35,58]

2.3. Regulatory Frameworks/Features Influencing SBC Project Delivery in SA

Regulatory features are defined as characteristics, including policies, legal frameworks, standards, and mandates, that can influence SBC adoption [9,32,59]. Consequently, this study proposes RFs that will guarantee successful SBC project delivery in SA. The most relevant literature sources were identified from 2013 to 2026 across major databases, including Scopus and Google Scholar. Government-related sources were also included. The RFs considered were tailored to suit the SA context. The following subsections discuss the selected RFs, while Table 2 presents the RFs with their supporting sources.

Table 2. Proposed RFs influencing SBC project delivery.

Measuring Variables	Sources
NBSA	[9,21,59–62]
NEMR	[63–65]
Legislation promoting the sustainable use of resources	[66–70]
Government as the primary driver, surpassing market forces	[9,71,72]
GBCSA standards	[73–75]
DPW GB Policy	[21,60,66]
Compulsory Evaluation of Sustainable Buildings	[42,76–79]
Compulsory Sustainable Construction Laws	[68,80,81]
Compulsory Certification for Sustainable Buildings	[9,68,82,83]
Compulsory Incentives for Organisations Adopting SBC	[69,84,85]
Incorporating environmental studies into construction legislation	[86–89]

2.3.1. National Building Standards Act (NBSA)

The NBSA provides the statutory foundation for building control and regulatory enforcement in SA [21]. Studies indicate that integrating sustainability standards into national building control legislation can lead to systematic improvements in performance, especially when enforcement is consistent and aligned with industry capacity [61,90]. Consequently, this act embeds minimum sustainability requirements into mainstream regulation, such as energy use and environmental sustainability [62]. It requires design and construction teams to plan, reschedule, or redesign to meet energy-efficiency criteria rather than treating them as optional add-ons [62]. Municipal approval and inspection hinge on compliance with these regulations, directly tying project timelines, cost and risk of refusal or re-submission to compliance [91]. Furthermore, this regulation was acknowledged as one of the Acts that support DPW's green building strategy to promote green building practices in SA [9,60]. However, these regulations are still undergoing refinement and

public consultation, highlighting ongoing challenges in codifying sustainability within core regulatory instruments [92].

2.3.2. National Environmental Management Regulations (NEMRs)

NEMRs, grounded in principles of environmental protection, sustainability, and intergenerational equity, influence how construction projects are permitted and executed [63]. These regulations aim to "provide for cooperative, environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for coordinating environmental functions exercised by organs of state; and to provide for matters connected therewith." [63]. Empirical research shows that NEMRs enhance environmental performance outcomes and increase compliance with ecological thresholds, thereby improving sustainability impacts that extend beyond the construction phase [64,67].

2.3.3. Legislation Promoting the Sustainable Use of Resources

SA's broader natural resource legislation, such as the National Water Act, the National Energy Efficiency Strategy, and the polluter-pays and sustainability principles embedded in regulations, influences how resources are accounted for in project design [66]. Projects that ignore resource sustainability may face stakeholder resistance or future regulatory constraints, thus influencing risk management strategies [67]

2.3.4. Government as the Primary Driver, Surpassing Market Forces

Government regulation and policy often lead the adoption of sustainability practices rather than leaving it to market demand alone. Studies suggest that voluntary uptake alone rarely meets national sustainability goals without mandates, incentives, enforcement, and government priority-setting [9,71,72]. Government policies can shape industry norms and expectations through mandatory Energy Performance Certificates (EPCs) and public sector Green Star requirements [93]. Developers often align project scope with likely future regulations to reduce compliance risk and attract public or private financing [94,95].

2.3.5. Green Building Council of SA (GBCSA) Standards

The GBCSA is a voluntary, non-profit body that develops sustainability certification systems, such as Green Star SA, and provides training for professionals to assess and improve the environmental performance of buildings [73,96]. Certification tools provide clear sustainability benchmarks, such as 4-Star and above, for best practices or leadership [97]. Projects aligned with these tools typically require early integration with sustainability specialists, energy modellers, and accredited designers, which influences design decisions and schedules. Certification can also increase marketability and stakeholder confidence, particularly in the private sector, where clients see Green Star ratings as competitive differentiators and indicators of quality and environmental responsibility [73,98].

2.3.6. Department of Public Works Green Building Policy (DPW GB Policy)

The DPW GB Policy outlines principles and actions to ensure that public sector projects lead in sustainability, including energy and water management, green procurement, and monitoring and reporting [66]. As part of recent government reforms, DPW has joined the GBCSA and committed to Green Star certification for new and existing buildings, with annual reporting on performance outcomes [99]. This policy drives resource planning and capability growth within government project teams, from procurement through operation, ensuring that long-term performance objectives are met rather than just construction completion [66].

2.3.7. Compulsory Evaluation of Sustainable Buildings

Compulsory evaluation of sustainable buildings refers to mandatory assessments, audits, or performance verification processes that construction projects must undertake to demonstrate compliance with sustainability standards [9]. Such evaluations are increasingly recognised as mechanisms for ensuring accountability and achieving measurable sustainability outcomes [76]. Scholars argue that compulsory evaluations establish transparent benchmarks and feedback systems that guide project teams toward sustainability objectives, influencing both design and implementation practices [42,77]. When embedded in regulatory frameworks, evaluation systems signal expected performance levels, reduce uncertainty, and align industry practices with policy goals [78,79]. However, mandatory evaluations may also extend project timelines and increase administrative costs, particularly where institutional capacity for implementation is limited [12,82].

2.3.8. Compulsory Sustainable Construction Laws

Compulsory sustainability laws embed environmental requirements into construction regulations, setting standards for energy efficiency, waste reduction, and environmental performance [68]. When effectively enforced, these legal frameworks can shift industry practices toward sustainable materials, energy-efficient designs, and environmentally responsible construction [80]. However, they may also increase costs and procedural complexity. In developing economies, weak enforcement, limited technical capacity, and fragmented institutional responsibilities often reduce their effectiveness in improving project delivery outcomes [12,100].

2.3.9. Compulsory Certification for Sustainable Buildings

Mandatory certification requires buildings to meet defined sustainability rating standards such as energy efficiency, water use, and material performance before approval for occupancy or financing. Certification systems like LEED, BREEAM, and Green Star are commonly used as benchmarks [9]. Research shows that compulsory certification can enhance project delivery quality, occupant comfort, and environmental performance by requiring measurable sustainability outcomes [83]. However, critics note that when certification is compulsory without appropriate support mechanisms, it may lead to compliance-oriented behaviour that prioritises documentation over meaningful sustainability performance [82]. Costs associated with certification fees and specialised expertise can also pose challenges for smaller firms and projects, affecting value for money and potentially deterring compliance where incentives are absent [101].

2.3.10. Compulsory Incentives for Organisations Adopting SBC

Compulsory incentive schemes embedded in legislation or policy are intended to encourage organisations to adopt sustainable construction practices [69]. These incentives may include tax credits, reduced permitting fees, priority approvals, or preferential access to public procurement linked to sustainability criteria [102]. Studies show that incentive-based regulations are most effective when combined with monitoring and enforcement mechanisms, as they reduce perceived financial risks and cost barriers to sustainable building adoption while stimulating innovation and investment in green technologies [84]. In SA and other developing contexts, such incentives can support SMEs by making sustainability adoption more economically feasible despite limited resources [9,90].

2.3.11. Incorporating Environmental Studies into Construction Legislation

The integration of environmental assessment requirements, such as environmental impact assessments (EIAs) and strategic environmental assessments (SEAs), into construction

legislation aims to embed sustainability considerations at early stages of project planning, ensuring that environmental and social impacts are evaluated before key development decisions are made [86]. When effectively integrated into legal frameworks, environmental studies can enhance project planning quality, improve risk identification, reduce ecological damage, and strengthen stakeholder engagement [87,88]. However, when EIAs are treated merely as procedural requirements rather than strategic decision-making tools, their effectiveness in promoting sustainable outcomes is limited, and their influence on project costs and schedules may be unclear [89].

2.4. Key Studies and Gap Identification

Sustainable construction has increasingly gained global attention as a critical pathway toward achieving environmental, social, and economic development goals. Within the CI, numerous studies have explored the role of regulatory frameworks, project management practices, and organisational dynamics in advancing sustainable building construction (SBC). However, despite growing advocacy, implementation remains inconsistent, particularly in developing countries such as South Africa [9,59].

A significant body of research emphasises the centrality of regulatory frameworks in driving sustainable construction practices. For instance, studies highlight that mandatory enforcement mechanisms, including regulations, assessments, certifications, and incentive schemes, are fundamental to effective SBC implementation [9]. The importance of regulatory environments is further reinforced by findings that identify key constructs such as compulsory enforcement and national green building policies as critical drivers of sustainability adoption [6]. Similarly, research on green procurement underscores the dominant role of government regulations, client requirements, and institutional pressures in facilitating sustainable practices within the construction sector [70]. These findings collectively suggest that strong, well-structured, and context-specific regulatory frameworks are indispensable for achieving sustainability objectives.

Despite these advancements, a persistent gap exists between sustainability-related legislation and its practical implementation. Empirical evidence reveals low levels of awareness and understanding of green building regulations among construction stakeholders, particularly at the operational level [21]. Moreover, discrepancies in attitudes between management and site-based personnel further hinder effective implementation. Institutional challenges, including limited capacity, political interference, and fragmented coordination, also contribute to weak environmental compliance, especially within municipal contexts [65]. These findings indicate that regulatory frameworks alone are insufficient without corresponding improvements in institutional capacity, stakeholder awareness, and organisational alignment.

Furthermore, the adoption of sustainable construction practices is influenced by a range of contextual and organisational factors. Studies conducted across different geographical settings identify key determinants, including technological capability, economic considerations, market dynamics, and stakeholder awareness [68,69]. Notably, financial constraints, a lack of incentives, and inadequate integration of design processes are frequently cited as major barriers to the adoption of sustainability. Conversely, targeted government interventions, such as tax incentives and policy support, have been identified as effective mechanisms for promoting sustainable practices [69]. The influence of company size and core business activities further underscores the need for tailored approaches that reflect the specific characteristics of industry actors.

In addition, regulatory evaluation studies indicate that while legislative frameworks have improved over time, challenges remain in ensuring their effectiveness. Comparative analyses show that environmental impact assessment (EIA) systems in different countries

exhibit similar levels of compliance with established criteria, yet still require refinement to address emerging environmental concerns [87]. This suggests that continuous policy improvement is necessary to align legislation with evolving sustainability goals. Moreover, comparative policy studies indicate that developed countries possess more comprehensive and well-implemented green building frameworks than developing nations, highlighting the need for stronger institutional structures and policy learning in countries such as South Africa [72].

At the individual level, research highlights the importance of behavioural and perceptual factors in driving sustainability practices. Project managers' perceptions of environmental regulations have been shown to significantly influence their adoption of environmentally sustainable project management practices, although this relationship is moderated by constraints such as cost and time [64]. This underscores the need to integrate sustainability into organisational performance systems and provide adequate support for practitioners.

Despite the valuable contributions of prior studies in identifying critical regulatory characteristics and framework components for sustainable building construction, important gaps remain. Earlier works [9,59] primarily focused on establishing and validating key regulatory constructs such as compulsory enforcement and national framework features using descriptive and factor-based analytical approaches. While these studies provided a strong conceptual and empirical foundation, they did not explicitly examine the causal relationships between these regulatory constructs and sustainable building construction project delivery (SBCPD).

Furthermore, much of the existing literature relies on perception-based assessments without advancing to more robust multivariate techniques capable of testing complex interrelationships among constructs. There is a noticeable lack of studies that employ structural equation modelling (SEM) to simultaneously validate measurement models and test hypothesised structural relationships in the context of sustainable construction. Additionally, although previous studies have drawn on data from built environment professionals, there remains a need for more focused, context-specific investigations that capture the perspectives of construction experts and practitioners within key economic hubs, such as Gauteng Province, where construction activities are highly concentrated.

To address these gaps, the present study extends prior research by employing SEM to rigorously test the influence of RF on SBCPD. By moving beyond factor identification to causal model validation, this study provides deeper insights into how regulatory frameworks translate into tangible project delivery outcomes.

Table 3 summarises the key literature reviewed and highlights the identified gaps.

Table 3. Summary of key literature and identified gaps.

Papers	Focus	Key Results	Conclusion	Gaps
Ref. [9]	Regulatory characteristics for SBC in SA	Mandatory enforcement, assessments, certifications, and incentives are critical	Strong regulatory enforcement is essential for SBC implementation	• Does not assess impact on project delivery outcomes (SBCPD) • Lacks causal modelling (e.g., SEM)

Table 3. *Cont.*

Papers	Focus	Key Results	Conclusion	Gaps
Ref. [21]	Gap between legislation and practice in SA construction	Poor awareness, selective compliance, weak implementation	Implementation lags behind legislation	• No quantitative validation • Limited to Western Cape • No link to project performance
Ref. [59]	Regulatory environment features for SBC in SA	Two constructs: compulsory enforcement & national policies	Regulatory features are significant for SBC adoption	• Does not test influence on SBCPD outcomes • Lacks structural modelling
Ref. [61]	Role of policies and standards in shaping "green" cities	Policies construct city identity and drive adoption	Government framing influences sustainability practices	• Lacks empirical testing • No project-level performance linkage
Ref. [64]	Influence of environmental regulations on project managers	Regulations positively influence practices, moderated by cost/time	Institutional pressure shapes behaviour	• Focuses on individuals, not project outcomes • No macro-level regulatory analysis
Ref. [65]	Environmental compliance in SA municipalities	Capacity, enforcement, and political support are key	Strong institutions improve compliance	• No construc-tion/project delivery focus • Qualitative only
Ref. [67]	Sustainability in project management (literature review)	Sustainability shifts scope, paradigm, and mindset of project management	Standards must evolve to incorporate sustainability	• Conceptual • Lacks empirical validation in construction context
Ref. [68]	Adoption of green specifications (China)	Influenced by policy, market, awareness, and economics	Targeted policies and incentives are needed	• Context-specific • No project delivery linkage • Limited applicability to developing countries like Africa
Ref. [69]	Sustainable construction practices (Chile)	Barriers: cost, a lack of incentives, design issues identified	Policy incentives needed to drive adoption	• No regulation–performance relationship tested

Table 3. *Cont.*

Papers	Focus	Key Results	Conclusion	Gaps
Ref. [70]	Green procurement in construction (Hong Kong)	Regulations are the strongest drivers	Government intervention is critical	• Does not link procurement to project outcomes
Ref. [72]	Comparative analysis of green building policies (USA, Netherlands vs. Africa)	Developed countries have more robust and effective policy frameworks	Developing countries should adopt stronger policies and increase awareness	• Lacks empirical testing of policy impact on SBCPD • No causal modelling (SEM) • Limited practitioner-level insights
Ref. [74]	Green certification trends in SA	Growth observed but uneven and clustered	Certification uptake increasing	• No assessment of impact on project delivery
Ref. [76]	Environmental compliance research trends	Identifies themes and emerging gaps	Calls for more governance-focused studies	• Lacks empirical modelling of regulatory effects
Ref. [78]	Regulatory compliance in SMEs (Uganda)	Compliance mediates sustainability practices	Regulations influence sustainability indirectly	• Not construction-focused; no delivery outcomes
Ref. [84]	Sustainability in megaprojects (Iran)	Awareness, governance, and corruption influence outcomes	Contextual factors shape sustainability	• Does not isolate the regulatory framework influence on SBCPD
Ref. [87]	Evaluation of EIA legislation (SA vs. Zambia)	Both countries are comparable; improvements over time	Continued refinement needed for effectiveness	• No analysis of enforcement or implementation performance
Ref. [89]	Effectiveness of Strategic Environmental Assessment (SEA) (Thailand)	Partial effectiveness achieved	SEA frameworks need strengthening	• No link to construction project delivery

2.5. Theoretical Foundations Underpinning the Study

2.5.1. Institutional Theory

This theory provides the primary theoretical lens for this study by explaining how organisational behaviour and project practices are shaped by formal rules, regulatory frameworks, and socially constructed norms within a given institutional environment [103,104]. Institutional theory identifies three dominant mechanisms through which institutional pressures influence organisational behaviour: coercive, normative, and mimetic pressures [103].

Coercive pressures arise from institutionalised rules, regulations, and policies enacted and enforced by governments and regulatory bodies [103,105]. Thus, the establishment of mandatory laws can compel construction organisations to integrate sustainability requirements into project planning, design, procurement, and construction processes, thereby directly shaping project delivery outcomes in terms of time, cost, quality, and environmental performance, inter alia.

Normative pressures emerge from professional norms, industry standards, and accreditation systems that define acceptable practice within the construction sector [105]. Standards developed by professional bodies and sustainability organisations, such as green building councils and certification agencies, establish benchmarks for sustainable building performance and influence how practitioners interpret regulatory requirements. These normative pressures can contribute to improved construction quality, enhanced health and safety outcomes, and increased stakeholder and end-user satisfaction by promoting consistency and professionalism across projects.

Mimetic pressures occur when organisations replicate practices perceived as successful or legitimate, particularly in environments characterised by uncertainty [106]. In SBC, firms may emulate projects that have successfully complied with regulatory sustainability requirements or achieved high sustainability ratings. This imitation can encourage innovation, the adoption of new construction technologies, and improved sustainability performance, although it may also result in standardised solutions that limit contextual flexibility.

Institutional theory thus provides a robust explanation for how regulatory environments shape SBCPD outcomes, particularly in contexts where voluntary market mechanisms are insufficient to drive sustainability adoption.

2.5.2. Regulatory Compliance Theory

Regulatory Compliance Theory complements Institutional Theory by focusing on the mechanisms through which organisations respond to regulatory requirements and the factors that influence compliance behaviour [107,108]. The theory posits that compliance is shaped not only by the threat of sanctions but also by perceptions of regulatory legitimacy, fairness, and the availability of incentives. In construction projects, compliance decisions are influenced by enforcement intensity, administrative complexity, organisational capacity, and perceived cost–benefit trade-offs associated with regulatory adherence [108,109]. In the context of SBC, regulatory compliance theory is particularly relevant to understanding how compulsory evaluation procedures, mandatory certification systems, and environmental regulations affect project delivery processes. Compliance with sustainability-related regulations often requires additional documentation, technical assessments, and coordination among project stakeholders, which can influence project timelines and costs. Where enforcement is strong and regulatory requirements are clearly communicated, compliance can lead to improved construction quality, environmental performance, and risk management. Conversely, weak enforcement or ambiguous regulations may encourage superficial or symbolic compliance, undermining sustainability outcomes [12,100].

The theory also highlights the role of incentive-based compliance, in which regulatory frameworks combine compulsory requirements with financial or procedural incentives to encourage compliance. Compulsory incentives for organisations adopting SBC, such as tax benefits, expedited approvals, or preferential procurement, can offset perceived compliance costs and improve value-for-money outcomes. In developing economies, where resource constraints are prevalent, such incentive mechanisms are critical for improving compliance levels and enhancing project delivery performance [69,84].

2.5.3. Stakeholder Theory

Stakeholder Theory provides an additional theoretical perspective by emphasising the importance of balancing the interests of multiple stakeholders involved in construction projects, including clients, end-users, regulators, contractors, consultants, and the broader society [110,111]. Sustainable building regulations are inherently stakeholder-oriented, as they seek to protect public interests related to environmental sustainability, health, safety, and social well-being. From a stakeholder perspective, regulatory frameworks influence project delivery outcomes by redefining stakeholder expectations and priorities. Mandatory sustainability standards can enhance transparency and accountability, thereby improving client confidence, stakeholder satisfaction, and end-user comfort. The government, acting as both regulator and client, assumes a dominant stakeholder role in shaping sustainability outcomes, particularly in public sector construction projects. Stakeholder theory thus supports the inclusion of non-traditional performance outcomes such as health, safety, comfort, and end-user satisfaction in evaluating SBC project delivery.

2.5.4. Market Failure

This theory further underpins this study by providing the economic rationale for government intervention in sustainable building construction [112]. Environmental degradation, climate change, and public health risks associated with construction activities represent negative externalities that are not adequately addressed through market mechanisms alone [42]. As a result, government intervention through compulsory regulations, standards, and incentives is necessary to internalise these external costs and protect public welfare. In developing economies, where market-driven demand for sustainable buildings is often limited by affordability constraints and information asymmetry, regulatory intervention becomes even more critical. Market failure theory, therefore, supports the study's focus on government as the primary driver of sustainable building construction, surpassing voluntary market forces and certification schemes. It also explains why short-term increases in project costs associated with regulatory compliance may be justified by long-term value-for-money gains and improved sustainability outcomes.

2.6. Hypothesis Development

The role of regulatory mechanisms in advancing sustainable building construction project delivery (SBCPD) has been widely emphasised in the literature. Compulsory enforcement and incentivisation (CEI) have emerged as critical instruments for ensuring compliance and driving sustainable practices within the construction sector. Empirical evidence indicates that mandatory regulations, including enforced standards, certification requirements, and incentive-based schemes, significantly enhance the adoption and implementation of sustainable construction practices [9,59]. Similarly, studies on green procurement highlight that government-imposed regulations and incentives are among the most influential drivers of sustainability adoption in construction projects [70]. These findings suggest that when sustainability requirements are not only prescribed but also enforced and incentivised, stakeholders are more likely to align their practices with sustainability objectives.

Conversely, weak enforcement mechanisms have been associated with poor compliance, low awareness, and fragmented implementation of sustainability initiatives [21,65]. This reinforces the argument that regulatory pressure, when combined with appropriate incentives, can positively influence project delivery outcomes by promoting adherence to sustainability standards. Based on this theoretical and empirical foundation, the following hypotheses are proposed:

H1$_0$: *CEI does not influence SBCPD.*

H1$_1$: *CEI influences SBCPD.*

In addition to enforcement mechanisms, the Sustainable Building National Framework (SBNF), comprising national policies, standards, guidelines, and strategic directives, plays a pivotal role in shaping sustainable construction practices. The literature suggests that a well-structured national framework provides coherence, direction, and consistency for sustainability implementation, thereby enhancing project delivery outcomes [59]. Furthermore, studies on sustainability adoption identify policy frameworks, regulatory support, and institutional arrangements as key determinants influencing the uptake of sustainable construction practices [68,69]. The presence of a robust SBNF enables stakeholders to align their practices with national sustainability goals and facilitates the integration of sustainability principles throughout the project lifecycle.

However, where national frameworks are inadequately developed, poorly enforced, or lack stakeholder awareness, implementation tends to be inconsistent and ineffective. This underscores the importance of a comprehensive, context-specific SBNF for achieving successful, sustainable construction outcomes. Accordingly, the following hypotheses are formulated:

H2$_0$: *SBNF does not influence SBCPD.*

H2$_1$: *SBNF influences SBCPD.*

These hypotheses are grounded in institutional theory, which posits that regulatory pressures and formalised frameworks significantly shape organisational behaviour and performance outcomes. It is therefore expected that both CEI and SBNF will have a significant influence on the delivery of sustainable building construction projects. These relationships will be empirically tested and further substantiated in Section 4 of this study.

3. Methodology

3.1. Research Design and Approach

A quantitative research design was employed to examine the influence of regulatory frameworks on sustainable building construction project delivery (SBCPD). The study followed a multi-stage approach, beginning with an extensive literature review to identify key regulatory features relevant to the South African context. Based on this review, 11 regulatory parameters were selected and operationalised into measurable variables.

Primary data were collected using a structured questionnaire designed to capture construction professionals' perceptions of the influence of regulatory mechanisms on SBCPD. The quantitative approach was deemed appropriate due to its suitability for statistical modelling and hypothesis testing, particularly using Structural Equation Modelling (SEM).

While it is acknowledged that sustainable construction project delivery may also be influenced by factors such as resource availability, personnel competence, and macroeconomic conditions, this study adopts a theory-driven, construct-focused approach grounded in institutional theory. Accordingly, the research isolates regulatory frameworks, specifically Compulsory Enforcement and Incentivisation (CEI) and the Sustainable Building National Framework (SBNF), as the primary explanatory variables. Non-regulatory factors were not explicitly modelled but are treated as background conditions assumed to be randomly distributed across respondents. The use of SEM further supports this approach by enabling the estimation of relationships between latent constructs while accounting for measurement error. Consequently, the model captures the net effect of regulatory

constructs on SBCPD without requiring the inclusion of all possible external variables. This delimitation is consistent with prior SEM-based studies, which focus on testing specific theoretical relationships rather than exhaustive determinants.

3.2. Questionnaire Design

The questionnaire was structured into three sections. Section A captured respondents' demographic and professional background, Section B focused on regulatory features influencing SBC project delivery, and Section C examined sustainable building construction project delivery (SBCPD) outcomes. Sections B and C utilised a 5-point Likert scale, where 1 represented "no extent," 2 "low extent," 3 "moderate extent," 4 "high extent," and 5 "very high extent." The use of a 5-point Likert scale was justified by its ability to reduce response bias, enhance reliability, and allow respondents to express moderate views through a neutral midpoint. Furthermore, Likert-scale data are widely recommended for SEM-based analysis, particularly in perception-based studies.

The key measurement questions were framed to align with the study objectives. In Section B, respondents were asked "To what extent does each regulatory feature influence SBC project delivery?" In Section C, the question was "To what extent will SBCPD outcomes be achieved if SBC is effectively practised due to the regulatory elements?" The variables and their corresponding literature sources were presented in Tables 1 and 2.

3.3. Validity and Reliability of the Measuring Instrument

The validity and reliability of the measurement instrument were established through multiple procedures. Face validity was confirmed through a pilot study involving 10 academic experts, ensuring the clarity and relevance of the questionnaire items [113]. Content validity was supported through expert review and ethical approval obtained from the University of Johannesburg [114]. Construct validity was assessed using Confirmatory Factor Analysis (CFA) to ensure all items loaded significantly on their respective constructs and met recommended model fit thresholds [115,116].

Convergent validity was demonstrated by Average Variance Extracted (AVE) values exceeding 0.50 and Composite Reliability (CR) values above 0.70 [117]. Discriminant validity was confirmed using the Fornell–Larcker criterion [118]. Reliability was further supported by Cronbach's alpha and composite reliability values exceeding 0.70, indicating a high level of internal consistency [117]. Collectively, these results confirm the robustness and suitability of the measurement scales for subsequent analysis.

3.4. Sampling Strategy and Data Collection

The study initially considered a random sampling approach; however, due to practical constraints in accessing respondents across South Africa within the study timeframe, it was replaced with convenience sampling. The questionnaire was distributed electronically via email and Google Forms to approximately 400 participants. Initial distribution efforts targeted professional bodies within the SA's broader built environment, including the South African Council for the Project and Construction Management Profession (SACPCMP), the South African Council for the Quantity Surveying Profession (SACQSP), the Engineering Council of South Africa (ECSA), the South African Council for the Architectural Profession, and the South African Council for Planners (SACPLAN). However, due to a low response rate, the study focused primarily on Gauteng Province, a major economic and construction hub in South Africa.

A total of 281 valid responses were obtained, representing a response rate of approximately 70%. This sample size is considered adequate for SEM analysis, as recommended thresholds suggest a minimum of 200 respondents and a maximum of 400 for large populations [30,119,120]. This also confirms the assertion that convenience sampling is beneficial when studying hard-to-reach populations or when time and resources are limited [121,122] and is suitable for exploratory studies aimed at hypothesis development [123].

To minimise sampling bias, only knowledgeable and experienced professionals involved in sustainability-related projects were included in the study. The respondents comprised professionals from diverse built environment disciplines, including quantity surveying, architecture, project management, construction management, engineering (civil, electrical, and mechanical), and urban planning. Selecting Gauteng Province enhances the study's contextual relevance, as the province hosts over 333,000 construction professionals and numerous construction firms [9]. It is also home to major cities such as Johannesburg and Pretoria and contributes approximately 33.9% of South Africa's GDP [124], making it an appropriate setting for examining sustainable construction practices and regulatory influences.

Moreover, by focusing on expert and practitioner perspectives in Gauteng, the study provides contextually grounded evidence that enhances both theoretical understanding and practical applicability of regulatory-driven sustainable construction in South Africa.

3.5. Data Analysis Procedures

Data were analysed using the Statistical Package for Social Sciences (SPSS) Version 29 and AMOS Version 30, following a four-stage analytical procedure. In the first stage, preliminary analysis was conducted to assess data suitability and reliability. Cronbach's alpha was used to evaluate internal consistency, yielding values of 0.92 for the RF variables and 0.95 for the SBCPD variables, indicating high reliability. Reliability improves as values approach 1.0 [125]. In addition, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were conducted. The KMO values of 0.889 for regulatory variables and 0.924 for SBCPD variables, along with statistically significant Bartlett's test results ($p = 0.001$), confirmed that the data were suitable for factor analysis, as KMO values above 0.60 and Bartlett's test p-values below 0.05 are considered acceptable.

In the second stage, Principal Component Analysis (PCA) was employed to reduce the dataset and identify underlying components among the regulatory variables, thereby establishing the structural grouping of the constructs. In the third stage, Confirmatory Factor Analysis (CFA) was conducted to validate the measurement model, ensuring that the observed variables adequately represented their respective latent constructs. Model fit indices were assessed against recommended thresholds to confirm the adequacy of the measurement model.

In the final stage, Structural Equation Modelling (SEM) was used to test the hypothesised relationships between the established exogenous and endogenous constructs. SEM enables the estimation of causal relationships among latent constructs while accounting for measurement error and unexplained variance attributable to non-modelled factors. This approach provides a robust framework for examining the influence of RF on SBCPD [126]. Figure 1 provides a summary of the four-stage level adopted in the data analysis.

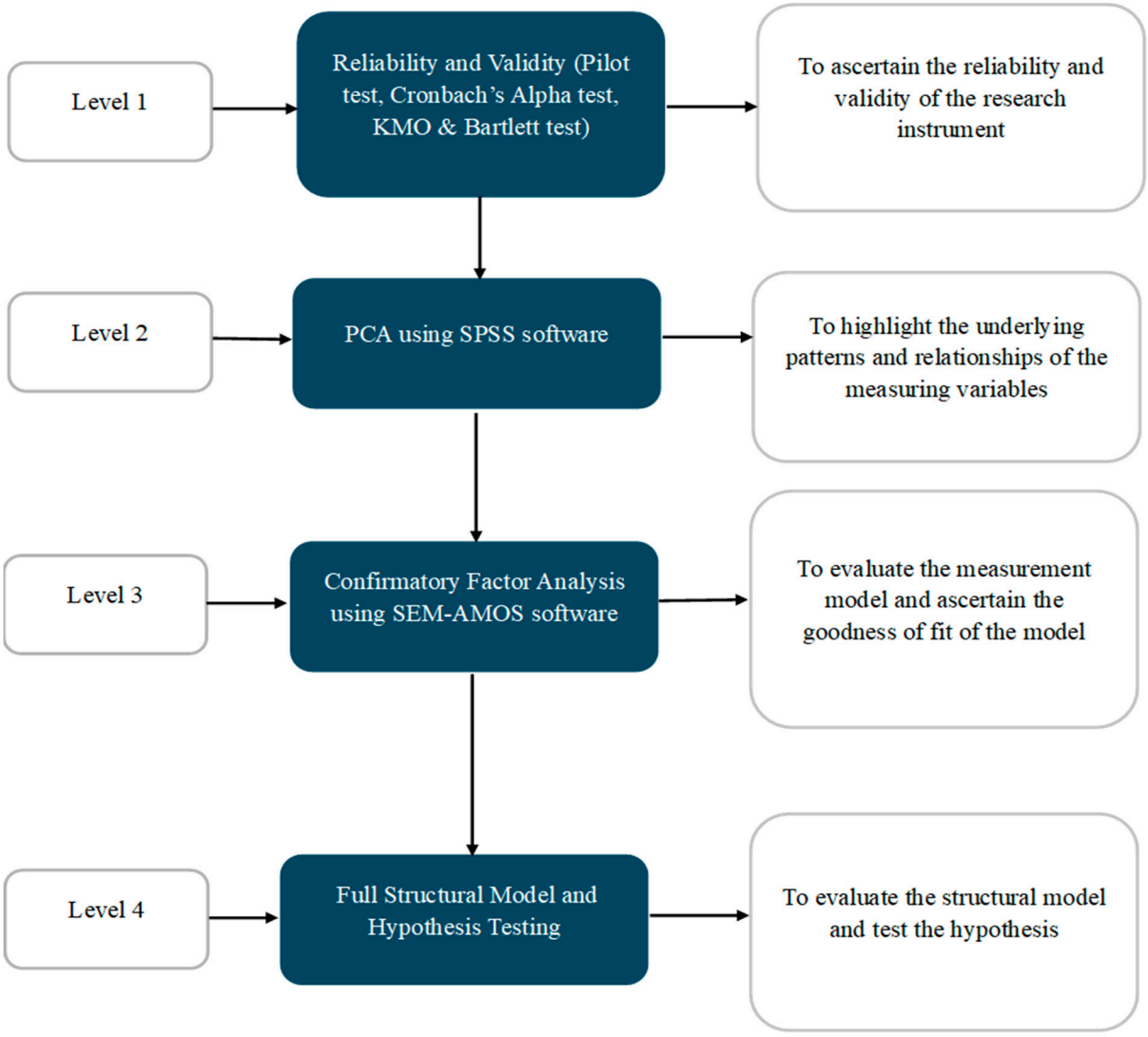


Figure 1. Data Analysis Procedures.

4. Results

4.1. Background Information

According to Table 4, "honours/btech degrees," "master's degrees," and "bachelor's degrees" were the top three qualifications among the participants of the study. On the other hand, "doctorate degree" was the lowest rank. The findings show that the respondents were the most intellectually qualified to answer the questions.

Also, many participants were from "construction management", "engineering", "quantity surveying", "project management", "architecture", and "town and urban/regional planning". This suggests that rather than architecture and urban planning in the built environment, the study's conclusions would be most useful in the engineering and CI.

Similarly, Table 4 shows that many participants were affiliated with "consulting firms" and "contracting firms". Those from "government agencies" were ranked third, while those from the "private sector were the least participants. The findings show that, when it comes to sustainability responses, the "consulting", "contracting", and "public sectors" consistently outperform the "private sector". These results are consistent with those of [127], which reported similar results for the organisational category.

Furthermore, Table 4 shows that many respondents had "six to ten" years of industrial experience. It was followed by those who had worked for "one to five" years, "eleven to

fifteen" years, "sixteen to twenty" years, "twenty-one to twenty-five" years, "twenty-six to thirty" years, "less than twelve months," and "more than thirty" years. The findings indicate that the participants in this study possess considerable expertise and are well-qualified to participate in the research.

Table 4. Respondents' profile.

Demographic	Category	%	Rank	Demographic	Category	%	Rank
Education background:	"Honours/Btech"	44.8%	1	Affiliation:	"Consulting firms"	34.5%	1
	"Master's"	24.2%	2		"Contracting firms"	26.3%	2
	"Bachelors"	14.6%	3		"Government agency"	24.9%	3
	"National diploma"	10.7%	4		"Private Sector"	14.2%	4
	"Doctorate"	5.7%	5				
Professional background:	"Construction Management"	21.4%	1	Years of experience:	"6 to 10 years"	19.6%	1
	"Engineering"	20.6%	2		"1 to 5 years"	18.1%	2
	"Quantity Surveying"	19.6%	3		"11 to 15 years"	15.7%	3
	"Project Management"	17.1%	4		"16 to 20 years"	14.6%	4
	"Architecture"	14.6%	5		"21 to 25 years"	11.4%	5
	"Town & urban/regional planning"	6.0%	6		"26 to 30 years"	8.1%	6
	"Other"	0.4%	7		"Less than 12 months"	6.8%	7
					"More than 30 years"	5.7%	8

4.2. Descriptive Statistics of Measuring Variables of Survey Results

Table 5 presents the regulatory environment factors influencing sustainable building construction (SBC) implementation for project delivery in South Africa. Respondents rated the extent of influence of each variable on a 5-point Likert scale (1 = no extent; 5 = very high extent). The mean (M) and standard deviation (SD) were used to rank the variables. All variables recorded high mean values (M = 3.86–4.22), indicating significant influence. The highest-ranked factor was "GBCSA standards" (M = 4.22; SD = 0.82), followed by "NEMR" (M = 4.15; SD = 0.81) and the "DPW green building policy" (M = 4.14; SD = 0.82). In contrast, "government as a driving force relative to the market" (M = 3.93; SD = 0.96) and "compulsory Incentives for organisations adopting SBC" (M = 3.86; SD = 0.93) were the lowest ranked, though still notable. Overall, the results indicate the significant influence of all regulatory factors. The measurement scale demonstrated strong reliability, with a Cronbach's alpha of 0.92, exceeding the recommended threshold of 0.70 [125].

Table 5. Descriptive analysis of regulatory frameworks (RFs) influencing SBCPD in SA.

Code	Measuring Variables	M	SD	Rank
RF1	NBSA	4.00	0.84	7
RF4	NEMR	4.15	0.81	2
RF5	Legislation promoting the sustainable use of resources	3.98	0.86	9
RF6	Government as the primary driver, surpassing market forces	3.93	0.96	10
RF2	GBCSA standards	4.22	0.82	1
RF3	DPW GB Policy	4.14	0.83	3
RF9	Compulsory Evaluation of Sustainable Buildings	4.08	0.91	6
RF10	Compulsory Sustainable Construction Laws	4.10	0.85	5
RF11	Compulsory Certification for SB	4.12	0.90	4
RF7	Compulsory Incentives for Organisations Adopting SBC	3.86	0.93	11
RF8	Incorporating environmental studies into construction legislation	4.00	0.86	7
	Cronbach's Alpha		0.92	

Conversely, descriptive analysis of the SBCPD variables is presented in Table 6, measured using a 5-point Likert scale (1 = no extent; 5 = very high extent). M and SD were used

for ranking. All variables recorded high mean values (M = 4.00–4.42), indicating strong perceived significance. The highest-ranked variables were improvement in sustainability rating (M = 4.42; SD = 0.78) and construction innovation (M = 4.40; SD = 0.71), followed by environmental objectives met (M = 4.35; SD = 0.71) and stakeholder/client satisfaction (M = 4.35; SD = 0.79). Although the latter two share the same mean, the lower SD for environmental objectives indicates greater consensus [128]. Finishing the project without going over budget (M = 4.03; SD = 0.79) and Project completion without going beyond the schedule (M = 4.00; SD = 0.82) ranked lowest, though both remained significant. The scale demonstrated excellent reliability, with a Cronbach's alpha of 0.95, exceeding the 0.70 threshold [125].

Table 6. Descriptive analysis of SBCPD outcomes.

Code	Measuring Variables	M	SD	Rank
SBCPD10	Upgrade in the sustainability rating	4.42	0.78	1
SBCPD9	Construction innovation	4.40	0.71	2
SBCPD7	Environmental objectives met	4.35	0.71	3
SBCPD4	Stakeholders/Client Satisfaction	4.35	0.79	3
SBCPD3	Fulfilment of the specified quality standards	4.32	0.73	5
SBCPD8	Health, safety, and comfort	4.32	0.74	5
SBCPD5	End-user satisfaction	4.31	0.76	7
SBCPD6	Value for money	4.30	0.75	8
SBCPD2	Finishing the project without going over budget	4.03	0.79	9
SBCPD1	Project completion without going beyond the schedule	4.00	0.82	10
	Cronbach's Alpha		0.95	

4.3. PCA of RF and SBCPD Outcomes

Table 7 showcases the PCA summary for RFs. According to the table, two main components with eigenvalues of 6.059 (55.082% variance) and 1.374 (12.488% variance) were extracted, yielding a total percentage variance of 67.570. The variables were significant, with communalities ranging from 0.588 to 0862 [125]. Cross-loading free variables were the only ones considered. The two components were named *Compulsory Enforcement and Incentivisation (CEI)* and *Sustainable Building National Framework (SBNF)*.

Likewise, Table 8 showcases the PCA summary for Sustainable Building Construction Project Delivery (SBCPD) features. According to the table, a single principal component with an eigenvalue of 7.113 was identified, accounting for 71.13% of the cumulative variance. Consequently, the component retained the name, Sustainable Building Construction Project Delivery (SBCPD).

Therefore, a multivariate model containing two latent exogenous constructs and one latent endogenous construct was developed, as shown in Figure 2. The model is henceforth referred to as an Integrated Regulatory Framework Model (IRFM). The hypotheses for the IRFM were stated as follows:

H1: *There is a relationship between CEI and SBCPD.*

H1$_0$: *CEI does not influence SBCPD.*

H1$_1$: *CEI influences SBCPD.*

H2: *There is a relationship between SBNF and SBCPD.*

H2$_0$: *SBNF does not influence SBCPD.*

H2$_1$: *SBNF influences SBCPD.*

Table 7. Summary of PCA for RFs.

Code	Variable	Component		Communality Extraction
		1	2	
RF9	Compulsory evaluation of sustainable buildings	0.918		0.862
RF10	Compulsory sustainable construction laws	0.896		0.836
RF11	Compulsory certification for SB	0.874		0.813
RF7	Compulsory incentives for organisations adopting SBC	0.649		0.618
RF8	Incorporating environmental studies into construction legislation	0.552	0.535	0.591
RF1	NBSA	0.728	0.743	0.555
RF4	NEMR		0.738	0.573
RF3	DPW GB Policy		0.729	0.696
RF6	Government as the primary driver, surpassing market forces		0.679	0.598
RF5	Legislation promoting the sustainable use of resources	0.541	0.640	0.702
RF2	GBCSA standards		0.617	0.588
Eigen values		6.059	1.374	
% variance		55.082	12.488	
Cumulative percentage variance		67.570		
Name of component		Compulsory Enforcement & Incentivisation (CEI)	Sustainable Building National Framework (SBNF)	

Table 8. Summary of PCA for SBCPD variables.

Code	Variable	Component	Eigen Value	% of Variance	Communality Extraction
		1			
SBCPD1	Project completion without going beyond the schedule	0.808	7.113	71.130	0.654
SBCPD2	Finishing the project without going over budget	0.788			0.621
SBCPD3	Fulfilment of the specified quality standards	0.870			0.756
SBCPD4	Stakeholders/Client Satisfaction	0.866			0.749
SBCPD5	End-user satisfaction	0.866			0.750
SBCPD6	Value for money	0.873			0.763
SBCPD7	Environmental objectives met	0.846			0.716
SBCPD8	Health, safety, and comfort	0.862			0.743
SBCPD9	Construction innovation	0.840			0.706
SBCPD10	Upgrade in the sustainability rating	0.809			0.655
Cumulative percentage variance				71.130	
Name of component		Sustainable Building Construction Project Delivery (SBCPD)			

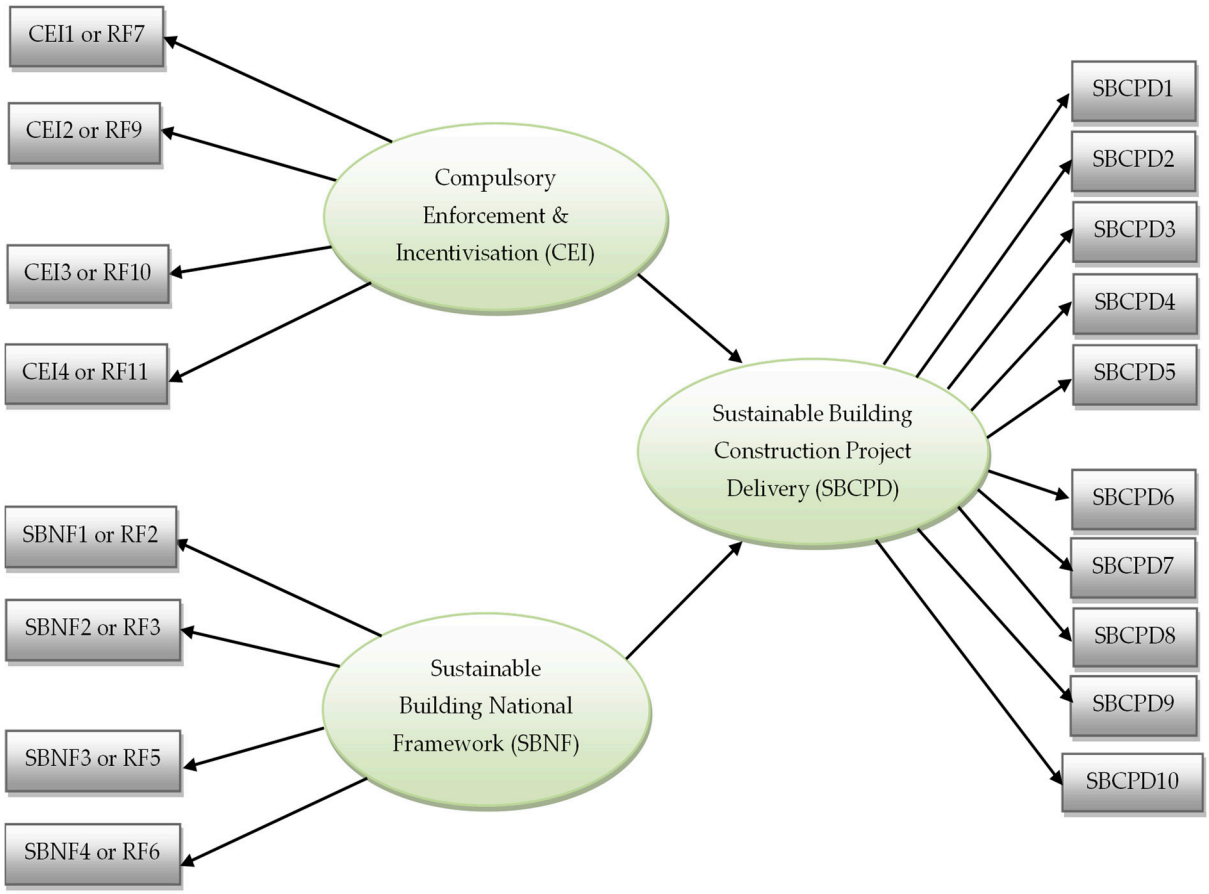


Figure 2. Integrated regulatory model for SBC.

4.4. Confirmatory Factor Analysis of Latent Constructs

The integrated regulatory framework model (IRFM), the hypothesised model in Figure 2, was evaluated for validity and goodness-of-fit using CFA. The measurement model for each IRFM construct was deemed sufficient. Table 9 portrays the "standardised regression coefficients" (r), "squared multiple correlations" (R^2), "critical ratio", "Cronbach alpha", "composite reliability" and "convergent validity" of each of the constructs. According to [58], regression loadings exceeding 0.55 should be retained. The standardised regression loadings for CEI, SBNF, and SBCPD ranged from 0.640 to 0.930, 0.679 to 0.912, and 0.599 to 0.760, respectively. As a result, the regression loadings accounted for almost half of the model's volatility. Similarly, the dependability and strong internal consistency of the measured variables were demonstrated by Cronbach's alpha for each construct, which ranged from 0.866 to 0.954 and exceeded 0.7 [129]. According to the composite reliability score, which ranges from 0.879 to 0.954 and exceeds 0.7, the constructs were also consistent, predictable, and dependable [129]. Additionally, the underlying latent constructs explain more than half (50%) of the variation in the belonging indicators. The average variance extracted for the constructs ranged from 0.647 to 0.728, indicating that convergent validity is empirically validated [130].

Table 10 showcases the IRFM fit indices, "x^2/df (3.457)," "SRMR (0.047)," "CFI (0.939)," "IFI (0.939)," "NFI (0.917)," "TLI (0.919)," and "GFI" (0.868). All showed a satisfactory or good fit for the model [126,131]. Likewise, the IRFM's discriminatory validity confirmed the model's appropriateness and the distinctive nature of its latent constructs.

Table 9. An overview of the CFA results for each of the IRFM latent constructs.

Latent Construct	Item	r	R^2	*p* @5%	α (≥0.70)	β (≥0.70)	Convergent Validity	
							AVE	√AVE
Compulsory Enforcement & Incentivisation (CEI)	CE19	0.911	0.830	Yes	0.904	0.913	0.728	0.853
	CEI10	0.927	0.859	Yes				
	CEI11	0.891	0.793	Yes				
	CEI7	0.656	0.431	Yes				
Sustainable Building National Framework (SBNF)	SBNF2	0.860	0.740	Yes	0.866	0.879	0.647	0.804
	SBNF3	0.896	0.802	Yes				
	SBNF5	0.746	0.556	Yes				
	SBNF6	0.699	0.489	Yes				
Sustainable Building Construction Project Delivery (SBCPD)	SBCPD1	0.774	0.600	Yes	0.954	0.954	0.676	0.822
	SBCPD2	0.741	0.549	Yes				
	SBCPD3	0.856	0.733	Yes				
	SBCPD4	0.855	0.730	Yes				
	SBCPD5	0.864	0.747	Yes				
	SBCPD6	0.873	0.762	Yes				
	SBCPD7	0.802	0.649	Yes				
	SBCPD8	0.857	0.734	Yes				
	SBCPD9	0.808	0.652	Yes				
	SBCPD10	0.783	0.614	Yes				

Note: r = standardised regression; *p* = significant; R^2 = squared multiple correlation; α = Cronbach alpha; β = composite reliability; AVE = average variance explained.

Table 10. CFA model fit indices for IRFM.

Index	Thresholds	Index Value	Remarks
"Chi-square (x^2/df)"	"Satisfactory (<5)"	3.457	Fulfilled
"Standardised root means square residual (SRMR)"	"Good fit (≤0.05)"	0.047	Fulfilled
"Comparative fit index (CFI)"	"Satisfactory (≥0.90)"	0.939	Fulfilled
"Increment fit index (IFI)"	"Satisfactory (>0.90)"	0.939	Fulfilled
"Normed fit index (NFI)"	"Good fit (≥0.80)"	0.917	Fulfilled
"Tucker–Lewis's index (TLI)"	"Satisfactory fit (>0.90)"	0.919	Fulfilled
Goodness of Fit Index	Acceptable/Satisfactory fit (>0.8)	0.868	Fulfilled

Table 11 indicates that each latent construct's square root of AVE was higher than the construct's intercorrelation value. Moreover, Figure 3 shows the CFA path diagram for the IRFM.

Table 11. Discriminatory validity for IRFM.

Constructs	CEI	SBNF	SBCPD
CEI	(0.853)		
SBNF	0.639	(0.804)	
SBCPD	0.307	0.465	(0.822)

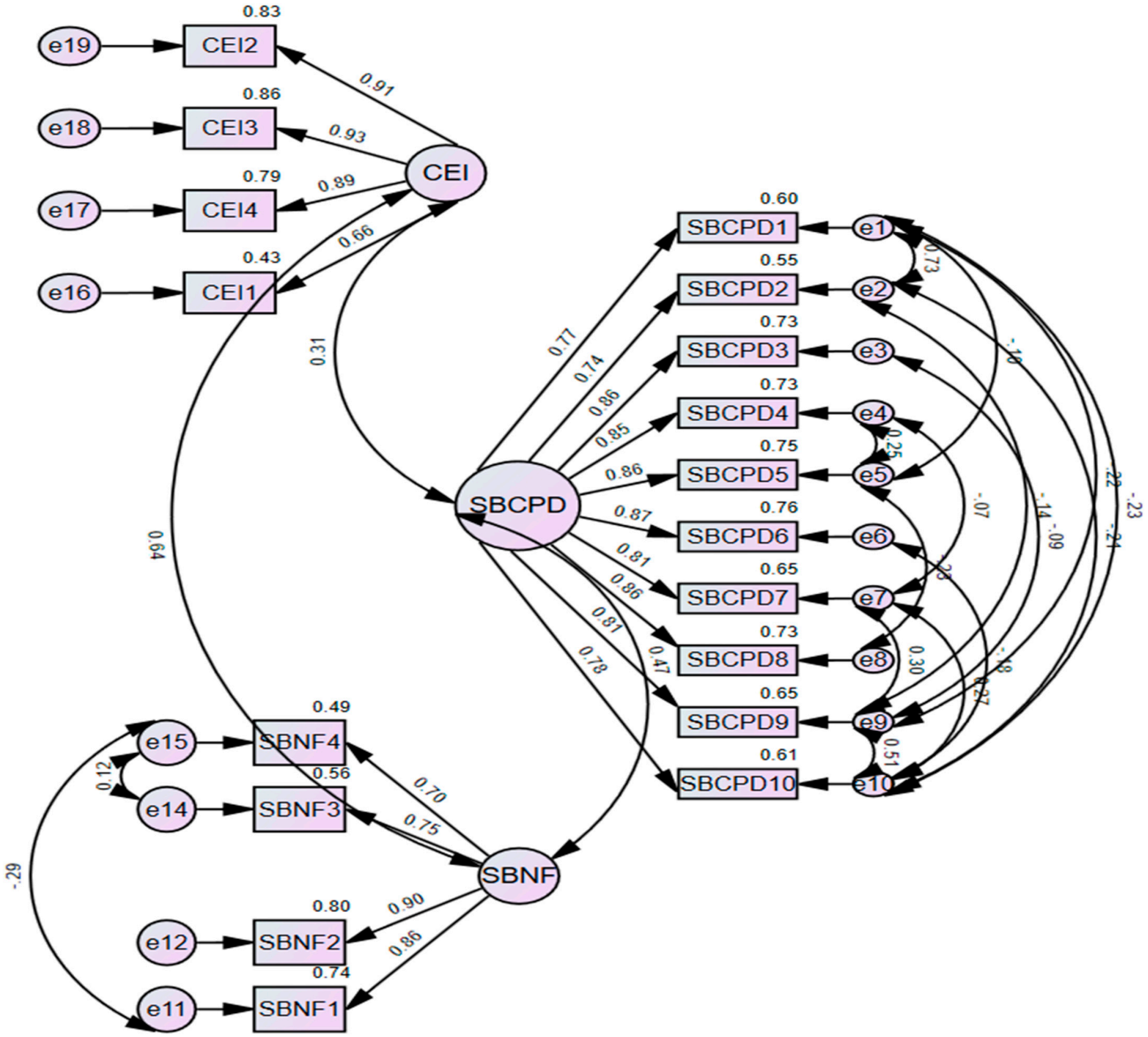


Figure 3. CFA path diagram for IRFM.

4.5. Structural Model

Both structural model evaluation and hypothesis testing were applied to the IRFM. The purpose of this model was to ascertain how the exogenous latent constructs (CEI and SBNF) influenced the endogenous latent construct (SBCPD). As a result, the final model used to measure the research constructs demonstrated complete goodness-of-fit. Table 12 presents the acceptable thresholds for the structural model's goodness-of-fit indicators. Consequently, the model achieved a satisfactory or good fit with "$\chi^2/df = 3.457$", "SRMR = 0.047", "CFI (0.939)", "IFI (0.939)", "NFI (0.917)", "TLI (0.919)", and "GFI" (0.868) [126,131]. Notably, the CFA was conducted as the measurement component of

the full SEM model; therefore, identical global fit indices are reported for both the CFA and structural model.

Table 12. Structural model fitness index.

Index	Thresholds	Index Value	Remarks
"Chi-square (x^2/df)"	"Satisfactory (<5)"	3.457	Fulfilled
"Standardised root means square residual (SRMR)"	"Good fit (≤0.05)"	0.047	Fulfilled
"Comparative fit index (CFI)"	"Satisfactory (≥0.90)"	0.939	Fulfilled
"Increment fit index (IFI)"	"Satisfactory (>0.90)"	0.939	Fulfilled
"Normed fit index (NFI)"	"Good fit (≥0.80)"	0.917	Fulfilled
"Tucker–Lewis's index (TLI)"	"Satisfactory fit (>0.90)"	0.919	Fulfilled
Goodness of Fit Index	"Acceptable/Satisfactory fit (>0.8)"	0.868	Fulfilled

4.5.1. Testing the Hypothesis of the IRFM

When all independent constructs were included simultaneously in the model, only the SBNF construct demonstrated a statistically significant effect on the dependent construct ($p < 0.000$) with a standardised regression weight (b) of 0.456. Therefore, $H2_1$ was supported. Conversely, the effect of the CEI construct was not statistically significant (b = 0.015, $p > 0.845$). Therefore, $H1_1$ was not supported. Table 13 presents the hypothesised relationship reports for the IRFM. This suggests that the SBNF construct explains the unique variance in the dependent construct, while the predictive effects of CEI may overlap with those of SBNF.

Table 13. Hypothesised relationship reports for the IRFM.

Path	Standardised Regression (β)	C.R	*p* Value	Decision
CEI → SBCPD	0.015	0.196	0.845	Insignificant
SBNF → SBCPD	0.456	5.193	0.000	Significant

Figure 4 portrays the structural path diagram for the IRFM.

4.5.2. Additional Individual Structural Tests

To further explore the relationships, additional analyses examined each independent construct separately in relation to the dependent construct. Table 14 indicates that each independent construct exhibited a statistically significant relationship with the dependent construct when tested individually. This indicates that, while the constructs are individually associated with the dependent construct, their shared explanatory power reduces the statistical significance of CEI when they are included simultaneously in the structural model.

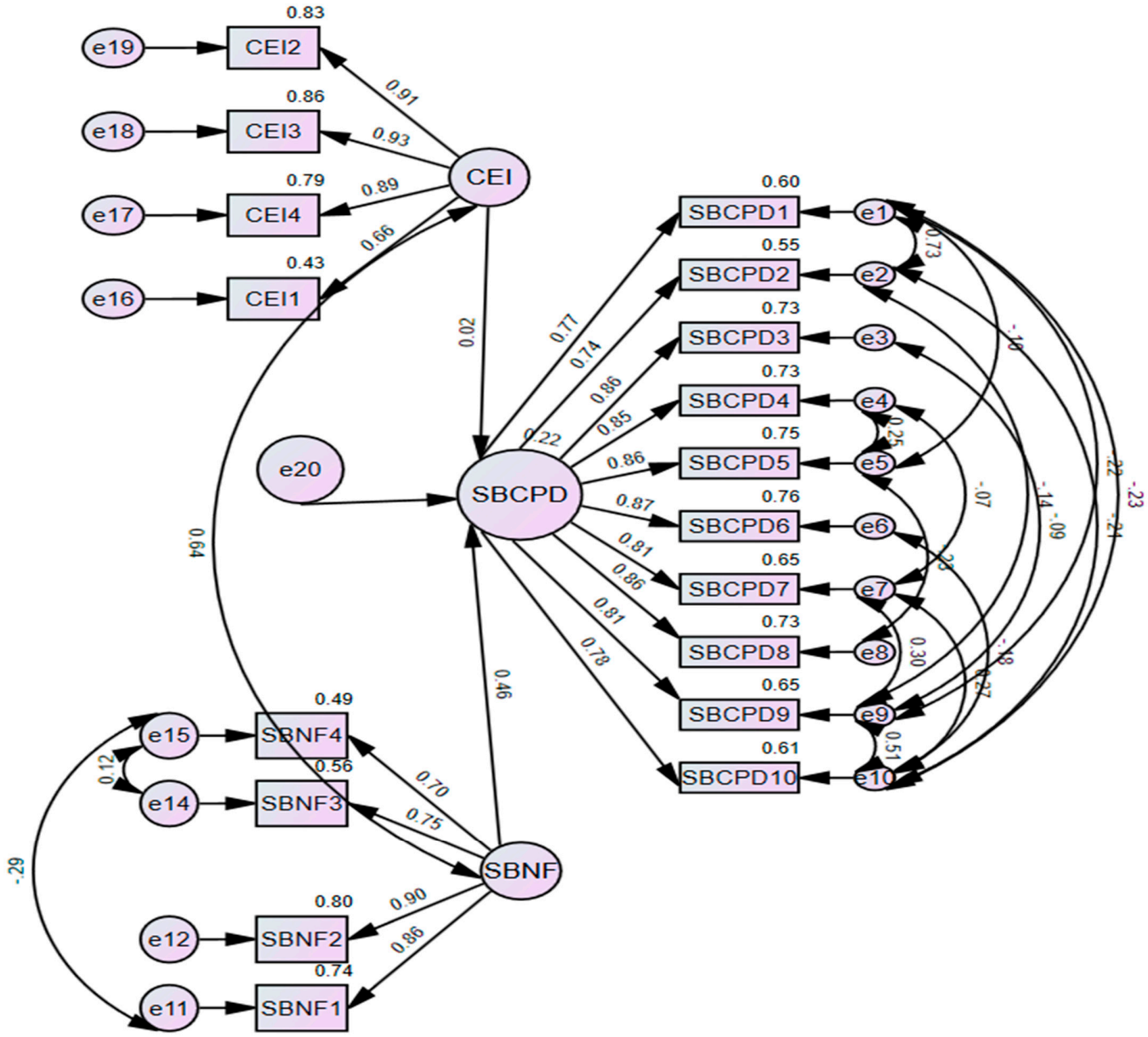


Figure 4. Structural path diagram for IRFM.

Table 14. Individual construct structural test.

Path	Standardised Regression (β)	C.R	*p* Value	Decision
CEI → SBCPD	0.305	0.462	0.000	Significant
SBNF → SBCPD	0.469	6.659	0.000	Significant

Figures 5 and 6 portray the structural path diagram for the independent latent constructs outside the IRFM.

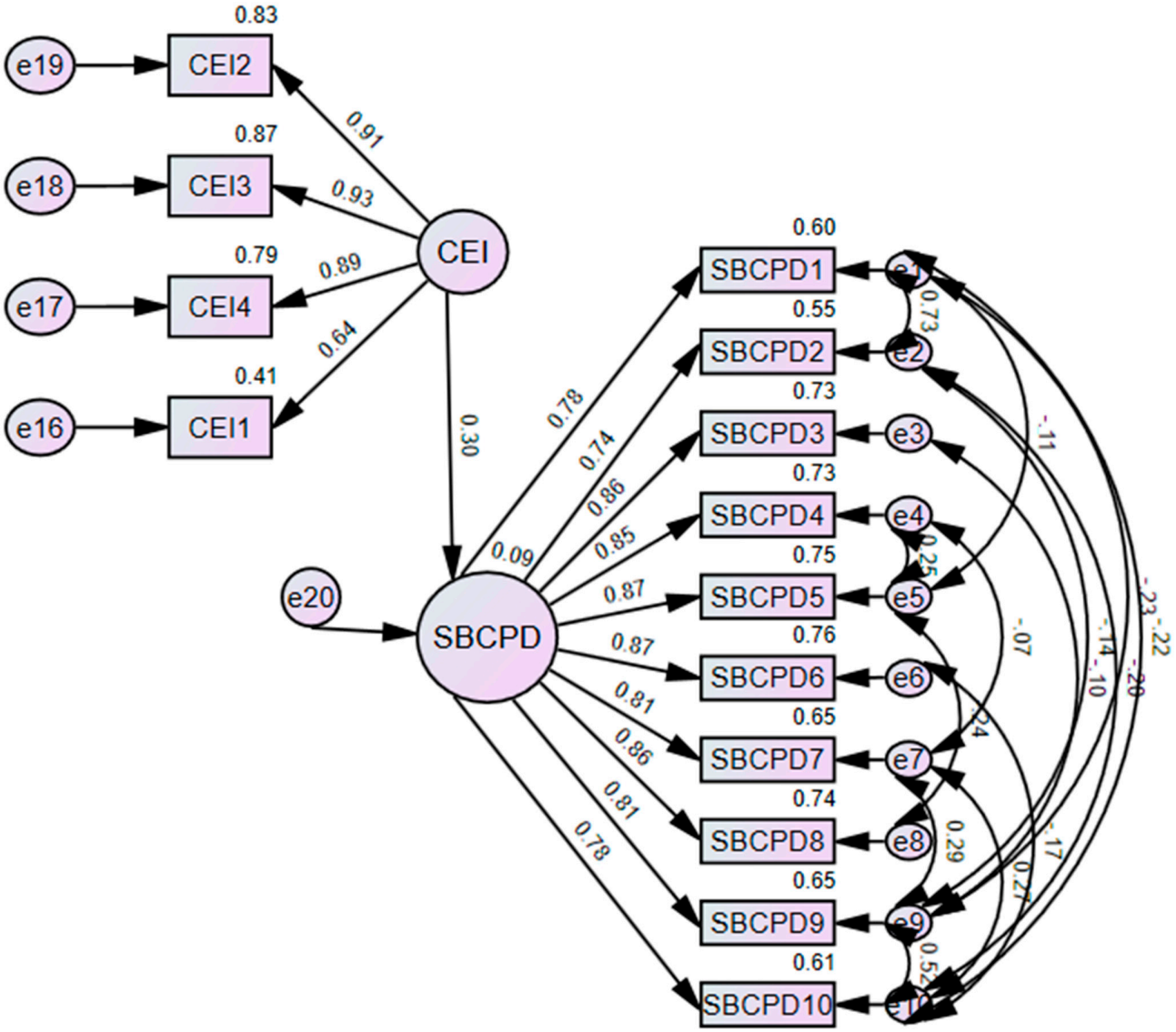


Figure 5. Individual structural test of CEI on SBCPD.

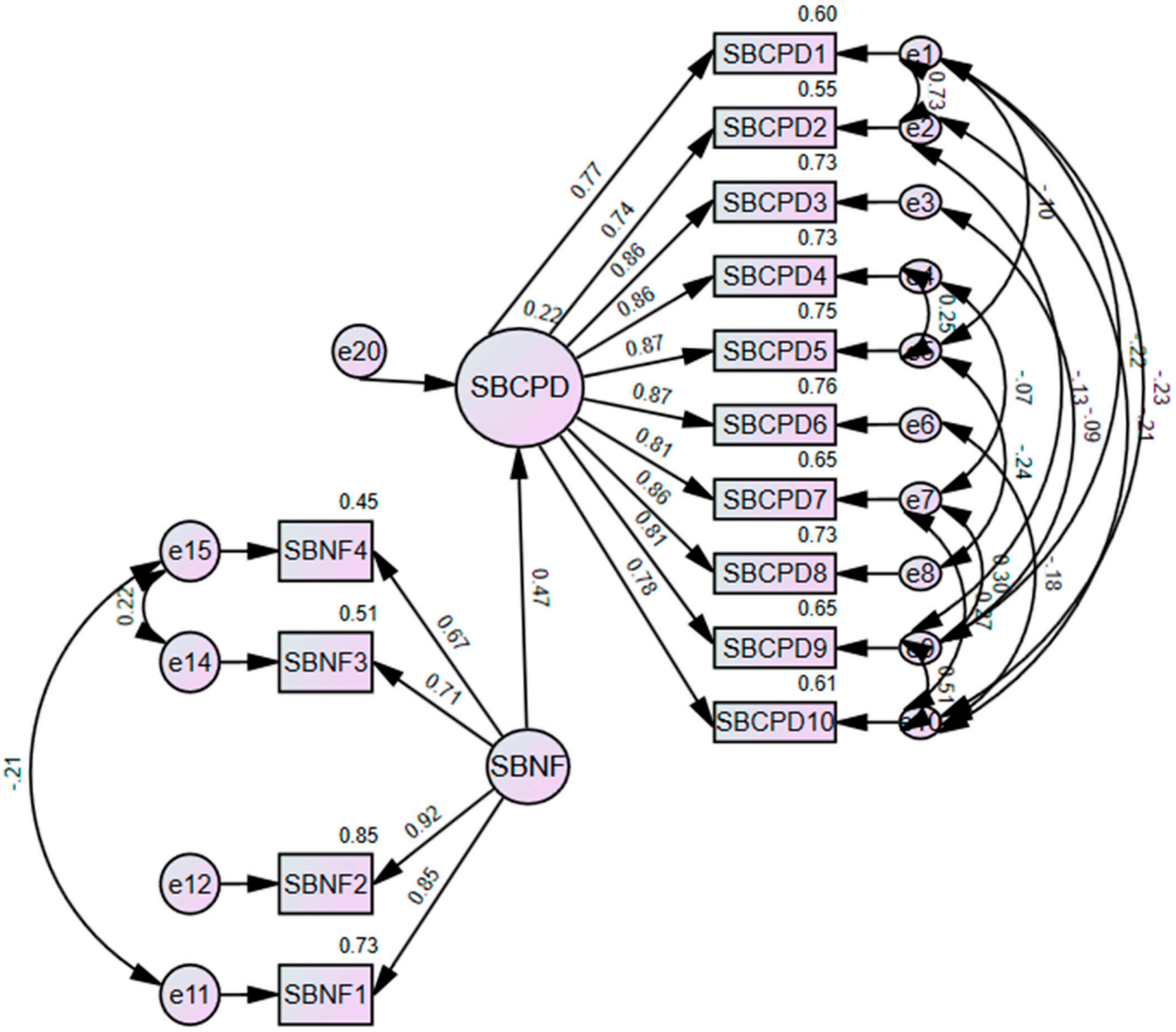


Figure 6. Individual structural test of SBNF on SBCPD.

5. Discussion

This extensive literature study and the exploratory factor analysis enabled the development of the research model hypotheses. Table 13 shows the results for each path in the IRFM, while Table 14 shows the results of each path outside the model. The test of the research hypotheses assesses the degree of RF's (CEI & SBCPD) influence on SBCPD.

5.1. H1: Relationship Between Compulsory Enforcement and Incentivisation (CEI) and SBCPD

The cluster CEI comprises compulsory evaluation of sustainable buildings, compulsory sustainable construction laws, compulsory certification for SB, and compulsory incentives for organisations adopting SBC. The model's testing results showed a statistically insignificant positive association between CEI and SBCPD at a 5% significant level. This suggests that model hypothesis ($H1_1$) is rejected. This result runs counter to the views of several authors and academics who argue that to successfully implement green procurement and sustainable construction, laws and regulations should be mandatory [68,69,81]. Ref. [81] argues that sustainability challenges in China require addressing, while Ref. [68] affirms that mandatory laws and policies are critical to the successful implementation of green specifications. Similarly, ref. [69] posits that government incentives and policies facil-

itate sustainable construction in Chile. However, the findings align with [132,133], which proposed voluntary standards for sustainable construction. Ref. [132] believes that it is more cost-effective to promote voluntary commitments to address environmental problems associated with sustainable construction. Consequently, this finding may be applicable to SA and other related developing countries until the issue of financial barriers and capacity constraints is resolved [12,100].

On the other hand, when the cluster was tested as a separate entity outside the model, the results were statistically significant and contributed positively, as shown in Table 14. Therefore, the results suggest that voluntary (e.g., GBCSA standards) and compulsory SBC laws cannot be combined, as their shared explanatory power reduces the statistical significance of CEI when they are included simultaneously in the structural model. According to ref. [132], when combined, voluntary and compulsory regulatory instruments should be well-articulated.

5.2. H2: Relationship Between Sustainable Building National Framework (SBNF) and SBCPD

The cluster SBNF comprises NEMR; the DPW GB Policy; Government as the primary driver, surpassing market forces; and the GBCSA standards. Most features in this cluster are already implemented in SA. The model's testing results showed a statistically significant relationship with SBCPD at a 5% significant level (p = 0.000), uniquely contributing about 46% to the model. Therefore, the hypothesis that SBNF influences SBCPD ($H2_1$) in SA is accepted. The findings provide insight into the growing influence of government policies in SA, especially the DPW GB policy and NEMRs. By institutionalising sustainability requirements in government projects, public sector leadership hopes to set a precedent for wider industry adoption. However, the practical impact of such policies has been limited due to limited enforcement capacity and difficulties with departmental coordination [134]. Also, the findings confirm the influence of the GBCSA certification system (Green Star) on shaping industry practices. This system provides performance benchmarks and encourages sustainable design, construction, and operation through an assessment and points-based model [9]. Furthermore, the findings align with market failure theory, with the Government as the primary driver, surpassing market forces. Hence, it is expedient for the SA government to be the main driver of SBCPD to curb affordability constraints and related issues.

6. Contribution to the Body of Knowledge

6.1. Theoretical Contributions

This study makes several important contributions to the advancing theoretical literature on sustainable construction and regulatory governance, particularly in developing country contexts.

First, this study advances understanding of the interaction between regulatory instruments by demonstrating that compulsory and voluntary mechanisms do not operate as a unified construct. While prior studies [68,69] largely assume that regulatory enforcement and incentives collectively enhance sustainable construction outcomes, the findings reveal a more nuanced reality. The statistically insignificant effect of the combined Compulsory Enforcement and Incentivisation (CEI) construct, in contrast to its significance when tested independently, highlights the presence of suppressor effects within regulatory frameworks. This contributes to theory by suggesting that regulatory hybridity requires conceptual separation rather than aggregation, particularly in SEM-based modelling of institutional drivers.

Second, this study extends institutional theory and market failure theory within the context of sustainable construction. The strong and significant influence of the Sustainable

Building National Framework (SBNF) confirms that state-led institutional mechanisms are more effective than market-driven or mixed regulatory approaches in developing economies [72,127]. This finding reinforces the proposition that, in contexts characterised by financial constraints and limited technical capacity [12,100], government intervention acts as a primary institutional force shaping industry behaviour.

Third, this study contributes to sustainable building construction (SBC) delivery theory by linking macro-level regulatory frameworks directly to project delivery performance (SBCPD). Unlike prior studies that focus on policy effectiveness in isolation, this research empirically demonstrates that well-structured national frameworks, such as NEMR, DPW GB policies, and GBCSA standards, can significantly influence project-level outcomes. This bridges the gap between policy-level constructs and project delivery performance, an underexplored area in existing literature. However, it is worth noting that the results were obtained from a survey.

6.2. Policy Implications

The findings provide several critical implications for policymakers, particularly within SA and similar developing economies.

Firstly, the results suggest that policy coherence is more important than policy intensity. The lack of significance of the CEI construct within the full model indicates that simply combining mandatory regulations with incentives does not necessarily yield improved outcomes. Policymakers should therefore avoid fragmented or overlapping regulatory instruments and instead ensure that voluntary standards and compulsory regulations are clearly differentiated and strategically aligned.

Secondly, the strong influence of the SBNF construct underscores the importance of government-led frameworks as catalysts for sustainable construction. This implies that policies such as the DPW GB policies and NEMRs should be further strengthened through:

- Improved enforcement mechanisms.
- Enhanced interdepartmental coordination.
- Capacity-building initiatives within public institutions.

Without these, the transformative potential of such frameworks may remain constrained, as discussed.

Thirdly, the findings reinforce the need for the government to act as the primary market driver. In line with market failure theory, reliance on private-sector initiative alone is insufficient in contexts such as SA. Policymakers should therefore:

- Expand public sector-led green procurement.
- Increase funding and financial incentives for sustainable projects.
- Support wider adoption of certification systems such as those developed by the GBCSA.

Lastly, this study suggests that gradual regulatory transition strategies may be more effective. Given the existing financial and capacity constraints, a phased approach that strengthens voluntary compliance mechanisms before enforcing strict mandates may yield better long-term outcomes.

6.3. Contribution to the CI

This study offers practical insights for construction professionals, developers, and industry stakeholders involved in sustainable building delivery.

Firstly, the findings highlight that alignment with national frameworks is critical to project success. Industry practitioners should prioritise compliance with established frameworks such as the following:

- National environmental regulations.

- Public sector green building policies.
- GBCSA certification systems.

These frameworks are shown to have a direct and significant impact on project delivery performance.

Secondly, this study reveals that over-reliance on regulatory enforcement without adequate capacity can be counterproductive. Contractors and developers should therefore not depend solely on compliance-driven approaches but instead adopt proactive sustainability practices, including the following:

- Early-stage sustainable design integration.
- Lifecycle cost analysis.
- Voluntary certification adoption.

Thirdly, the findings suggest that voluntary and mandatory systems require strategic navigation. Firms that effectively integrate both without treating them as interchangeable are likely to achieve better performance outcomes. This implies the need for the following:

- Internal sustainability policies.
- Organisational capacity development.
- Training and upskilling in green construction practices.

Similarly, the findings suggest that, due to constraints on SBC adoption in developing countries and SA, voluntary adoption currently has a greater and more positive influence until the barriers are drastically mitigated or eradicated.

Finally, this study underscores the importance of public sector projects as industry benchmarks. Contractors engaged in government-led projects are more likely to develop competencies that can be transferred to private sector projects, thereby accelerating industry-wide transformation.

7. Conclusions

This study evaluates the influence of regulatory features/frameworks (RFs) on Sustainable Building Construction Project Delivery (SBCPD) within the SA context using AMOS-SEM. The features were organised into two latent constructs for analysis and evaluated across three phases: PCA, CFA, and the structural model. PCA was used to highlight the underlying patterns and relationships among the measurement variables and to group them into clusters. Similarly, CFA was used to validate the measurement model of the clusters/components in the structural model. The findings reveal a complex relationship between regulatory mechanisms and project delivery outcomes.

The results indicate that while Compulsory Enforcement and Incentivisation (CEI) does not significantly influence SBCPD when modelled as a combined construct, it demonstrates significance when assessed independently. This suggests that integrating voluntary and mandatory regulatory instruments may dilute their effectiveness, underscoring the need for clearer policy articulation and conceptual separation.

In contrast, the Sustainable Building National Framework (SBNF) emerged as a strong and significant predictor of SBCPD, contributing substantially to the model. This underscores the critical role of government-led frameworks, policies, and institutional mechanisms in driving sustainable construction outcomes in SA. The findings further confirm that in developing economies, government intervention remains the primary driver of sustainability adoption, surpassing market-based mechanisms. Overall, this study concludes that achieving effective SBCPD requires the following:

- Coherent and well-structured regulatory frameworks.
- Strong government leadership and enforcement capacity.
- Strategic alignment between voluntary and mandatory instruments.

The study advances both theory and practice by offering empirical data on the differential impacts of regulatory constructs and offering actionable insights for policymakers and industry stakeholders. Future research should explore additional contextual factors, such as financial mechanisms and organisational capacity, to further refine the understanding of sustainable construction delivery in emerging economies.

8. Limitations of the Study

Notwithstanding the contributions of this study, several limitations should be acknowledged. First, this study was conducted primarily within Gauteng Province, which may limit the generalisability of the findings to other provinces or national contexts with differing regulatory environments. Future studies may therefore extend the geographical scope to enhance external validity.

Second, the study employed a convenience sampling approach due to practical constraints associated with accessing professionals with the requisite expertise. Data collection was conducted primarily through online platforms, including email distribution and Google Forms, circulated via multiple recognised professional bodies within the built environment. While this approach facilitated access to a relevant and knowledgeable sample, it may have excluded professionals who are less digitally engaged or not affiliated with such organisations. This introduces the potential for self-selection bias, whereby individuals with greater awareness of or interest in sustainable construction practices are more likely to participate. Consequently, the findings may reflect the perspectives of a more engaged subset of professionals, potentially influencing the observed relationships.

Third, the dependent construct, Sustainable Building Construction Project Delivery (SBCPD), was measured based on respondents' perceptions rather than objective project performance data. Participants were required to assess the extent to which project delivery outcomes would be achieved under effective implementation of sustainable construction practices. As such, the findings reflect anticipated or perceived outcomes rather than empirically observed project performance. Therefore, while the study demonstrates that professionals who perceive regulatory frameworks as influential are more likely to expect improved delivery outcomes, it does not provide direct causal evidence that such frameworks lead to actual performance improvements in practice.

Fourth, this study focused exclusively on regulatory determinants of sustainable building construction project delivery (SBCPD), namely Compulsory Enforcement and Incentivisation (CEI) and the Sustainable Building National Framework (SBNF). While other factors, such as resource availability, workforce competence, and macroeconomic conditions, may also influence SBCPD, they were not incorporated in the present model. This was intentional, as the study aimed to isolate and examine the structural role of regulatory governance mechanisms within an institutional theory framework. Future research may extend this model by integrating organisational, economic, and technical variables to develop a more comprehensive predictive framework.

Finally, this study examined the effects of independent constructs on the dependent construct as a whole. Future research should extend the analysis to the level of individual observed variables, using item-level SEM, multi-group comparisons, or second-order factor models. Such approaches would provide richer insights into which specific indicators are most influenced and help identify mediating or moderating mechanisms underlying the relationships. Nevertheless, the authors aim to fill these gaps in further studies.

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Abbreviations

The following abbreviations are used in this manuscript:

BREEAM	Building Research Establishment Environmental Assessment Method
CEI	Compulsory Enforcement and Incentivisation
CFA	Confirmatory Factor Analysis
CI	Construction Industry
DPW	Department of Public Works
GB	Green Building
GBCSA	Green Building Council of South Africa
IRFM	Integrated Regulatory Framework Model
LEED	Leadership in Energy and Environmental Design
NBSA	National Building Standards Act
NEMR	National Environmental Management Regulation
PCA	Principal Component Analysis
RF	Regulatory Frameworks/Features
SA	South Africa
SBC	Sustainable Building Construction
SBCPD	Sustainable Building Construction Project Delivery
SBNF	Sustainable Building National Framework
SEA	Strategic Environmental Assessment
SEM	Structural Equation Modelling

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