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UIC (university-industry collaboration) is essential for bridging the gap between academic research and practical innovation, particularly in developing economies. This study investigates the key drivers and outcomes of UIC within South Africa's higher education and industrial context, with a specific focus on professionals in the built environment disciplines. Using PLS-SEM (partial least squares equation modelling), the study examines the influence of five exogenous constructs – governmental support and policy environment (GOV), organisational design and institutional capacity (ORG), technology transfer and innovation ecosystems (TECH), collaborative networks and social capital (NET) and knowledge transfer mechanisms (KNOW) – on UIC strength and four performance outcomes: innovation and creativity, skill development and graduate employability, knowledge creation and transfer, and research impact on local industry. The research was conducted in the Gauteng Province, South Africa's economic hub and a key centre for construction and infrastructure development. A survey instrument was administered to 204 professionals across academic, government and industry sectors engaged in built environment fields. The findings revealed that GOV, TECH and KNOW were the strongest predictors of UIC effectiveness, while ORG and NET exhibited moderate influence. In turn, UIC strength significantly enhanced all four higher education performance outcomes, with particularly strong effects on innovation and graduate employability. This study contributes novel insights by centring built environment professionals, an often-overlooked stakeholder group, in the UIC discourse. It concludes with policy and practical recommendations for promoting inclusive and sustainable UIC frameworks aligned with national development priorities.

Keywords: construction industry; graduate employability; higher education institution; knowledge transfer; skills development; UIC (university-industry collaboration).

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Introduction

In the context of the 4IR (Fourth Industrial Revolution) and increasing economic complexity, UIC (collaboration between universities and industry) has become a pivotal strategy to drive innovation, knowledge exchange and economic development (Petersen & Kruss, 2019; Aliu & Aigbavboa, 2021; Kamal et al., 2024). Particularly in South Africa's built environment sector, which includes construction, engineering, architecture and related disciplines, the rapid advancement of digital technologies, sustainability standards and urbanisation challenges require coordinated efforts between academia and industry (Mutongoza, 2025). According to the South African Council for Scientific and Industrial Research (CSIR, 2020), the construction sector contributes approximately 4.5% to the country's GDP but faces persistent productivity and skills gaps that hinder growth and competitiveness (Habiyaemye et al., 2022). Universities serve as hubs of knowledge creation, yet without effective linkages to industry, academic research risks remaining isolated and underutilised (Aliu & Aigbavboa, 2021). The National Development Plan (NDC, 2019) explicitly highlights the need to strengthen university-industry collaboration as a key enabler to support skills development, technology transfer and innovation in strategic sectors such as infrastructure and construction (Mutongoza, 2025). This aligns with global trends showing that nations with strong university-industry partnerships experience higher rates of innovation and economic resilience (Zhuang et al., 2025). For South Africa, where the built environment sector is pivotal for economic transformation and employment generation, encouraging dynamic partnerships between universities and industry actors is essential to bridge the gap between research and practice, enhance workforce readiness, and address socio-economic challenges related to urban growth and sustainability.

Despite these recognised needs, empirical evidence remains limited on how key factors – such as knowledge transfer mechanisms, governmental support, organisational design, collaborative networks, and technology transfer – interact to drive effective UIC in South Africa's built environment sector. Moreover, the conceptualisation and measurement of UIC remain contested. UIC is multilayered, involving diverse forms such as joint research projects, consultancy, technology licensing, student internships and workforce training (Al Harrasi & Al Subhi, 2024). Studies reveal a lack of consensus on standard metrics for evaluating UIC effectiveness; traditional indicators like patent counts or licensing revenues often fail to capture the relational and knowledge-sharing dimensions critical to sustainable partnerships (Kamal et al., 2024). In the South African context, research by Mutongoza (2025) shows that relationship quality, trust and organisational alignment are significant determinants of successful UIC,

underscoring that collaboration is not merely transactional but relational. Many measurement frameworks also neglect the socio-economic context in which UIC operates, including disparities in institutional capacity, funding, and regulatory environments characteristic of developing economies (Aliu & Aigbavboa, 2021). The built environment sector, in particular, faces challenges in codifying collaboration outputs, as knowledge exchange often involves tacit knowledge, complex project-based interactions, and long innovation cycles (Petersen & Kruss, 2019). Therefore, there is a pressing need for integrative frameworks that consider both tangible and intangible outcomes of UIC – such as innovation diffusion, skills enhancement, and policy impact – to provide a holistic assessment of these partnerships' value and sustainability.

While prior studies such as Petersen and Kruss (2019), Aliu and Aigbavboa (2021), Lubbe et al. (2021) and Mutongoza (2025) have laid foundational insights into the drivers and challenges of UIC in South Africa, there remains a notable gap in empirically examining how these collaborations function specifically within the built environment sector, a critical yet underexplored area given its economic and developmental significance. Existing research often highlights broad themes such as knowledge transfer, trust and organisational alignment, but tends to treat UIC outcomes in a fragmented manner, with limited attention to the interplay between structural, policy and technological factors within this sector (Lubbe et al., 2021). Moreover, many studies struggle to capture the multilayered nature of collaboration outputs beyond conventional measures like patents or licensing, neglecting important relational and socio-economic dimensions that shape collaboration effectiveness in South Africa's unique institutional context.

To address these gaps, the present study adopts an integrative approach that systematically investigates key determinants of UIC in South Africa's built environment sector, including knowledge transfer mechanisms, governmental support, organisational design, collaborative networks and technology transfer. Using PLS-SEM (partial least squares equation modelling), the study examines the strength and significance of relationships among these constructs and their impact on collaboration outcomes such as research output, skills development, and workforce readiness. Guided by this framework, the study seeks to answer the following research questions: (1) How do knowledge transfer mechanisms, governmental support, organisational design, collaborative networks, and technology transfer influence the effectiveness of university-industry collaboration? (2) What are the overall impacts of

university-industry collaboration on creativity, research output, skills development and meeting the sector's demand for qualified professionals? The outcomes are expected to provide empirically grounded insights for policymakers, industry leaders and academic institutions to inform targeted interventions, promote sustainable partnerships and enhance alignment between higher education outputs and national development priorities in South Africa.

Theoretical framework

Reviewing the concept of university-industry collaboration

UIC (university-industry collaboration) represents a form of strategic partnership in which academic institutions and industry entities interact with the aim of sharing expertise, advancing innovation and jointly solving practical challenges (Aliu & Aigbavboa, 2021; Kamal et al., 2024). In this study, the foundation for understanding UIC is informed by the theory of social capital, which emphasises the collective value embedded in relationships, shared norms and trust among participants (Al-Tabbaa & Ankrah, 2019). Social capital reflects the strength and quality of networks and the reciprocity that emerges within those associations, both critical components when universities and industries work toward mutual goals. The collaborative efforts between universities and industry actors are particularly relevant in knowledge-intensive and technology-driven sectors, where innovation increasingly arises from complex, inter-organisational relationships. According to Ćudić et al. (2022), social capital facilitates the flow of tacit knowledge and informal cooperation, which are essential in dynamic problem-solving environments like the built environment. In this context, partnerships between universities and construction firms, architectural practices, engineering consultancies, or government infrastructure agencies are structured around knowledge-sharing and mutual value creation, aligning with the conceptual premise that organisations benefit from accessing external knowledge reservoirs (Kamal et al., 2024).

UIC is often framed as a bilateral or multi-stakeholder process in which academic researchers and industry professionals co-develop technologies, train skilled personnel, or create platforms for applied research. As Mutongoza (2025) suggests, these collaborations are designed not only to generate research outputs but also to address practical industry challenges and societal needs. In South Africa's built environment sector, such partnerships are increasingly seen as critical to bridging the gap between theoretical knowledge and on-site application, particularly as the country faces an urgent need for sustainable infrastructure,

improved project delivery, and technical capacity building (Habiyaemye et al., 2022). In today's globalised economy, where knowledge is a prime resource, universities are recognised as vital contributors to national innovation systems. As their roles evolve beyond traditional teaching and research, many institutions are embracing their identity as 'entrepreneurial universities' (Meissner et al., 2022). This shift implies greater involvement in commercial activities, such as patent development, spin-offs and consultancy services. In parallel, industries are proactively engaging with universities to access emerging technologies, recruit well-trained graduates and reduce the risks associated with innovation (Al-Tabbaa and Ankrah, 2019). These reciprocal interests have catalysed new models of cooperation, especially in countries like South Africa where policy agendas, such as the NDP (National Development Plan) 2030, emphasise public-private partnerships in education and infrastructure development.

For universities, the incentives for entering UIC include aligning academic outputs with national development goals, accessing alternative funding streams, exposing students to real-world challenges, and enhancing the employability of graduates (Kamal et al., 2024). From the perspective of industry, collaboration offers a route to reduce innovation costs, develop talent pipelines, enhance technical capabilities and strengthen its social license to operate. Companies that invest in university partnerships may also benefit from reputational gains and improved competitiveness in an increasingly innovation-driven marketplace (Meissner et al., 2022). Kamal et al. (2024) provide a useful classification of collaborative formats based on the degree of integration between academic and industry partners. At one end, 'Gamma' collaborations reflect low levels of direct interaction, where industries fund research but allow academic partners full autonomy over content and direction. 'Beta' relationships denote a more engaged model, where industry partners help shape research agendas. The most integrated form, 'Alpha', involves industry directing research efforts closely, often to meet immediate business objectives; however, such arrangements are typically rare, as balancing industry satisfaction with academic rigour and novelty is challenging (Kamal et al., 2024). These models are highly relevant to South Africa's built environment, where some partnerships, such as joint curriculum design or structured internship programmes, fall into the Beta category, while others, such as bespoke consulting for large-scale infrastructure projects, lean toward the Alpha model.

UIC also has non-monetary benefits. For example, collaborations between architecture schools and city planning departments in South Africa have led to community-based urban

regeneration projects, where students gain field experience while municipalities benefit from fresh design perspectives (Morkel et al., 2023). Similarly, some engineering departments are partnering with local construction firms to pilot green building technologies, creating platforms for experimentation that would otherwise be too risky for industry alone. These kinds of partnerships help build long-term social value and foster reputational gains for both universities and firms (Stephen & Aigbavboa, 2025). Moreover, universities provide an important conduit for small- and medium-sized enterprises (SMEs) to access R&D capabilities they otherwise lack. In the built environment, many SMEs do not have the internal capacity for technological development or advanced design work. Collaborating with universities gives them access to laboratories, data analytics tools and highly trained interns or researchers (Aliu & Aigbavboa, 2021).

This mirrors trends in European countries, where public funding mechanisms actively support such SME-university linkages (Al-Tabbaa & Ankrah, 2019). Institutional culture also plays a critical role in shaping the scope and quality of UIC. According to Kamal et al. (2024), universities that promote entrepreneurship, offer incentives for applied research, and maintain strong industry-facing leadership are more likely to engage in high-impact collaborations. In the South African context, however, bureaucratic hurdles, misalignment of goals and limited communication between faculty and firms often act as barriers. Additionally, researchers may lack the training or incentives to prioritise industry-oriented work, while firms may underestimate the strategic value of academic partnerships and the importance of academic rigor and novelty in postgraduate research (Mutongoza, 2025).

(H1) Collaborative networks and social capital factors and UIC

Collaborative networks and the quality of social capital are increasingly recognised as vital enablers of effective UIC. These networks provide the foundation for trust, knowledge sharing and mutual engagement, allowing institutions to leverage both formal structures and informal relationships. In particular, dimensions of social capital – such as trust between partners, shared values, long-standing personal relationships and engagement with local communities – play a central role in strengthening UIC. The presence of robust networks fosters stronger inter-institutional ties and enhances the effectiveness of collaborative innovation ecosystems (Stephen & Aigbavboa, 2025). Formal partnerships between universities and industries (NET1) are especially important for structured engagement. These partnerships often involve

memoranda of understanding, joint research centres, and innovation hubs that institutionalise collaboration. For example, South Africa's Centres of Excellence, supported by the Department of Science and Innovation (DSI) and the NRF (National Research Foundation), exemplify structured collaborations where universities and industries co-create knowledge and align research priorities (DSI-NRF, 2020). Equally important are informal relationships (NET2), which help navigate bureaucratic challenges and sustain trust. Researchers and industry professionals often maintain long-standing personal relationships that facilitate smoother communication, enhance mutual understanding, and increase commitment to collaborative projects (Petersen & Kruss, 2019). Informal social capital complements formal agreements and is instrumental in initiating new projects or maintaining ongoing collaborations. Engagement with local communities (NET3) strengthens social capital by embedding partnerships within broader socio-economic contexts. Community involvement ensures that research addresses real-world challenges and aligns academic pursuits with societal needs. UICs in South Africa's energy and housing sectors have shown that community participation enhances both the relevance and social impact of collaborative projects (Habiyaemye et al., 2022). Finally, inclusive networks must prioritise historically disadvantaged institutions (NET4). Involving these institutions helps reduce inequalities in research capacity, ensures equitable distribution of collaboration benefits, and expands the reach of social capital across the national research ecosystem. Programmes like the University Capacity Development Programme have been instrumental in fostering inclusive partnerships between historically advantaged and disadvantaged universities in South Africa (Woldegiorgis & Chiramba, 2025). Taken together, these elements suggest that trust, shared values, personal relationships, community engagement and inclusivity within collaborative networks are key dimensions of social capital that positively influence effective UIC. Thus, it is posited that:

collaborative networks and social capital have a positive influence on effective UIC (H1).

(H2) Governmental support and policy environment

Governmental support and the policy environment play a critical role in shaping and sustaining UIC. Public sector involvement often provides the necessary resources, regulatory frameworks and strategic direction to facilitate effective partnerships that drive innovation and economic growth. In particular, government funding (GOV1) is a critical enabler that reduces financial barriers for joint research and development initiatives, enabling universities and industries to undertake high-impact projects that might otherwise be unfeasible (Kamal et al., 2024).

National policies promoting university-industry partnerships (GOV2) reflect a government's strategic commitment to innovation-driven development. In South Africa, the National Development Plan (NDP, 2019) explicitly emphasises strengthening UIC to accelerate skills development, technology transfer and sectoral competitiveness – particularly within priority sectors such as infrastructure and the built environment (Mutongoza, 2025). Complementary to these policies, the DSI implements frameworks that incentivise collaboration, including tax credits and research grants tailored to foster co-innovation (DSI-NRF, 2020). Innovation agencies (GOV3) such as the Technology Innovation Agency serve as critical intermediaries by providing not only funding but also technical support, capacity building and networking opportunities for collaborative projects. These agencies help bridge gaps between academia and industry, ensuring that research outputs are aligned with market demands, and can be effectively commercialised (Woldegiorgis and Chiramba, 2025). The presence of such agencies significantly enhances the translation of research into practical applications, especially for SMEs within the built environment sector. Moreover, government initiatives (GOV4) must be responsive to the specific needs of local industries to maximise impact. Tailored programmes that consider the unique challenges of South Africa's built environment sector, such as skills shortages, infrastructural backlogs and sustainability imperatives, can better support collaborations that address pressing socio-economic issues (Habiyaemye et al., 2022). This alignment improves the relevance and effectiveness of UIC, fostering innovation ecosystems that contribute to national development goals. Taken together, these factors reiterate the critical role of governmental support and policy environment in cultivating successful UICs. Hence, the study hypothesises that:

governmental support and enabling policy environment have a positive influence on effective UIC (H2).

(H3) Knowledge transfer mechanisms

Knowledge transfer is a fundamental element underpinning the success of UIC, serving as the conduit through which academic research is translated into practical applications and innovative solutions. Effective knowledge transfer mechanisms enable continuous learning, innovation and capacity building, which are essential for addressing complex challenges in sectors like South Africa's built environment. Central to this process are joint research projects (KNOW1), which facilitate direct collaboration between university researchers and industry

practitioners, fostering mutual understanding and co-creation of knowledge (Kamal et al., 2024). Co-supervision of postgraduate students by both academic and industry experts (KNOW2) is a critical mechanism that bridges theoretical knowledge with practical experience. This approach not only enhances the students' research relevance and employability, but also strengthens the linkages between institutions, ensuring that emerging talent is attuned to industry needs. In South Africa's construction and engineering sectors, such collaborative supervision is increasingly recognised as a best practice to develop skills aligned with market demands (Aliu & Aigbavboa, 2021). Workshops and seminars (KNOW3) play a crucial role as structured platforms for knowledge exchange. They provide opportunities for disseminating research findings, discussing emerging trends, and building networks that support ongoing collaboration (Habiyaemye et al., 2022). These events promote transparency, trust and engagement, which are vital for sustaining long-term partnerships. Furthermore, they enable the diffusion of tacit knowledge that may not be easily codified through formal documentation. Staff exchanges or secondments (KNOW4) represent an immersive knowledge transfer method where personnel move between university and industry settings temporarily. This facilitates deeper experiential learning, fosters cultural understanding, and enhances the capacity of both parties to innovate collaboratively (Lubbe et al., 2021). Particularly in the built environment sector, where projects are complex and multidisciplinary, such exchanges help align academic inquiry with real-world industry challenges. Together, these knowledge transfer mechanisms contribute to more effective, dynamic and sustainable UIC. Therefore, this study hypothesises that:

knowledge transfer mechanisms positively influence effective university-industry collaboration (H3).

(H4) Organisational design and institutional capacity

Organisational design and institutional capacity also play a key role in shaping the effectiveness and sustainability of UIC. The presence of dedicated university units tasked with coordinating partnerships (ORG1) facilitates streamlined communication, strategic alignment and efficient management of joint initiatives (Al-Tabbaa and Ankrah, 2019). Such units act as critical intermediaries, ensuring that collaboration objectives are clear, resources are effectively allocated and mutual expectations are managed. Equally important is the clarity of procedures within industry partner companies for engaging with academic institutions (ORG2). Clear

protocols help reduce administrative bottlenecks, enhance transparency, and build trust, which are vital for fostering long-term collaborative relationships (Aliu & Aigbavboa, 2021). In South Africa, where organisational complexities and regulatory frameworks can pose challenges, having well-defined engagement processes supports smoother collaboration, particularly in sectors like construction and engineering that involve multiple stakeholders (Petersen & Kruss, 2019). Addressing historical inequalities and promoting inclusion within collaboration efforts (ORG3) are essential considerations in the South African context, characterised by its diverse socio-economic landscape and legacy of institutional disparities (CSIR, 2020). Inclusive collaboration frameworks help ensure that disadvantaged institutions and communities benefit from knowledge sharing and capacity building, thereby contributing to broader social equity and sustainable development (Mutongoza, 2025). This inclusive approach aligns with the National Development Plan's objectives to reduce inequalities through enhanced skills development and innovation. Effective communication between universities and industry (ORG4) underpins all successful collaborations. Open, transparent and consistent communication fosters mutual understanding, manages expectations, and mitigates conflicts (Petersen & Kruss, 2019). It also supports the co-creation of knowledge and adaptation to evolving project needs, which is particularly important in the dynamic and project-driven built environment sector. Consequently, strong organisational structures and institutional capacity enhance the university-industry interface, enabling collaborations to thrive amidst complexity. This study hypothesises that:

organisational design and institutional capacity positively influence effective university-industry collaboration (H4).

(H5) Technology transfer and innovation ecosystems

Technology transfer and innovation ecosystems represent critical mechanisms that facilitate the practical application of academic research within industry, thereby driving economic growth and competitiveness. TTOs (technology transfer offices) serve as essential conduits by managing the commercialisation process, protecting intellectual property, and bridging the gap between research outputs and market needs (TECH1) (Rocha et al., 2023). In South Africa, where innovation adoption faces structural challenges, effective TTOs help ensure that research generated within universities reaches commercialisation pathways, contributing to local economic development (Lubbe et al., 2021). Innovation hubs, science parks and incubators provide fertile ecosystems that nurture collaboration between universities, industries and

startups (TECH2). These environments promote knowledge exchange, resource sharing, and networking opportunities critical to accelerating innovation cycles (Aliu & Aigbavboa, 2021). For example, South Africa's Innovation Hub in Pretoria and the CiTi (Cape Innovation and Technology Initiative) have been instrumental in supporting partnerships within the built environment sector by fostering multidisciplinary collaboration and enhancing technology adoption (CSIR, 2020). SMEs frequently lack the internal capacity or resources to develop or adopt new technologies independently. Therefore, university support for SMEs (TECH3) through technology transfer initiatives plays a significant role in promoting inclusive innovation and sectoral growth (Lubbe et al., 2021). Facilitating technology adoption among SMEs enables these firms to remain competitive and contribute to broader economic objectives, especially in developing economies where SMEs constitute a significant employment base (Mutongoza, 2025). University support for patenting and intellectual property protection (TECH4) further safeguards innovations, incentivises researchers, and attracts industry investment (Kamal et al., 2024). This protective infrastructure is vital to maintaining trust and ensuring that both academic and commercial partners benefit equitably from joint research activities. In due course, collaborations driven by strong technology transfer and innovation ecosystems lead to the development of new products or services tailored for local markets (TECH5), thus reinforcing the economic and societal relevance of university research (Lubbe et al., 2021). Based on these considerations, this study posits that:

technology transfer and innovation ecosystems positively influence effective university-industry collaboration (H5).

(H6) The influence of UIC on higher education performance

UIC plays a vital role in driving innovation and creativity by bringing together academic research and practical industry challenges. This partnership promotes an environment conducive to creative problem-solving and the development of new technologies, often resulting in innovative solutions that may not arise within isolated academic settings (Kamal et al., 2024). For instance, South African universities collaborating with construction companies have successfully developed sustainable building materials, demonstrating how UIC can spark creative breakthroughs that address pressing real-world problems (OUTCOME 1: Innovation and Creativity (Kadhila et al., 2024)). Beyond innovation, UIC significantly enhances skills development and graduate employability by providing students with hands-on experiences that bridge the gap between theoretical learning and practical application (Aliu &

Aigbavboa, 2021). Opportunities such as internships, jointly supervised research projects and industry input into curriculum design ensure that graduates are better prepared to meet workforce demands. Studies reveal that students graduating from universities with strong industry connections tend to have higher employment rates and skills more closely aligned with market needs (OUTCOME 2: Skill Development and Graduate Employability (Lubbe et al., 2021)). Moreover, UIC facilitates dynamic knowledge creation and transfer, promoting a two-way exchange where universities gain insights into industry challenges while sharing research outputs that improve technological and operational capabilities (Habiyaemye et al., 2022). This flow of knowledge enables academic programmes to remain current and relevant by integrating emerging industry trends and challenges, fostering curricula that respond to evolving sector requirements (OUTCOME 3: Knowledge Creation and Transfer). Finally, collaborative research partnerships have a tangible impact on local industry competitiveness and productivity. By jointly developing innovative solutions, improving processes, and supporting the adoption of new technologies, UIC strengthens industry performance (Al-Tabbaa and Ankrah, 2019). In South Africa's built environment sector, for example, university-led research has contributed to advancements in construction methodologies, enhanced safety protocols and more sustainable building practices, thus supporting economic growth and social development (OUTCOME 4: Research Impact on Local Industry (CSIR, 2020)). Together, these outcomes illustrate the broad and meaningful influence UIC exerts on higher education and its role in fostering innovation, skills, knowledge, and industrial advancement. Thus, this study posits that:

university-industry collaboration positively influences innovation and creativity, skills development and graduate employability, knowledge creation and transfer and research impact on local industry (H6).

Table 1 and Figure 1 present the measurement items and the conceptual framework underpinning this study, respectively.

Table 1: *Measurement items for constructs, their codes and supporting literature*

Code	Indicator description	Construct (variable label)	Key references
GOV1	The government provides funding that supports university-industry collaboration.	Governmental Support and Policy Environment (GOV)	Aliu and Aigbavboa (2021); Habiyaremye et al. (2022); Kamal et al. (2024)
GOV2	National policies promote partnerships between universities and industries.		
GOV3	Innovation agencies provide support for collaborative projects.		
GOV4	Government initiatives meet the needs of local industries.		
ORG1	The university has units that coordinate with industry partners.	Organisational Design and Institutional Capacity (ORG)	Lubbe et al. (2021); Habiyaremye et al. (2022); Kamal et al. (2024)
ORG2	Industry partners have clear procedures for working with universities.		
ORG3	Collaboration efforts address historical inequalities and promote inclusion.		
ORG4	Communication between universities and industry is effective.		
TECH1	Technology transfer offices help bring university research to market.	Technology Transfer and Innovation Ecosystems (TECH)	Aliu and Aigbavboa (2021); Lubbe et al. (2021); Kamal et al. (2024); Aliu et al. (2025)
TECH2	Innovation hubs or science parks support university-industry partnerships.		
TECH3	SMEs are supported in adopting technologies from universities.		
TECH4	The university supports patenting and intellectual property protection.		
TECH5	Collaboration leads to new products or services for the local market.		
NET1	There are strong formal partnerships between universities and industry.	Collaborative Networks and Social Capital (NET)	Petersen and Kruss (2019); Aliu and Aigbavboa (2021); Lubbe et al. (2021); Zhuang et al. (2025)
NET2	Personal relationships help support collaboration.		
NET3	Projects include engagement with local communities.		
NET4	Disadvantaged institutions are included in collaboration networks.		
KNOW1	Joint research projects are common in our collaboration.	Knowledge Transfer Mechanisms (KNOW)	Petersen and Kruss (2019); Habiyaremye et al. (2022)
KNOW2	Postgraduate students are co-supervised by university and industry experts.		
KNOW3	Workshops or seminars are used to share knowledge.		
KNOW4	Staff exchanges or secondments help transfer knowledge.		
OUTCOME 1	Innovation and creativity	University-Industry Collaboration Outcomes (OUTCOMES)	Aliu and Aigbavboa (2021); Habiyaremye et al. (2022)
OUTCOME 2	Skill development and graduate employability		
OUTCOME 3	Knowledge Creation and Transfer		
OUTCOME 4	Research Impact on Local Industry		

Research methodology

Design of study

This study adopts an empirical and cross-sectional design to examine the drivers of UIC (university-industry collaboration) and its associated outcomes, specifically in the areas of research impact, graduate employability, innovation, skills development and knowledge transfer. A structured questionnaire was employed to collect quantitative data from professionals within the built environment sector.

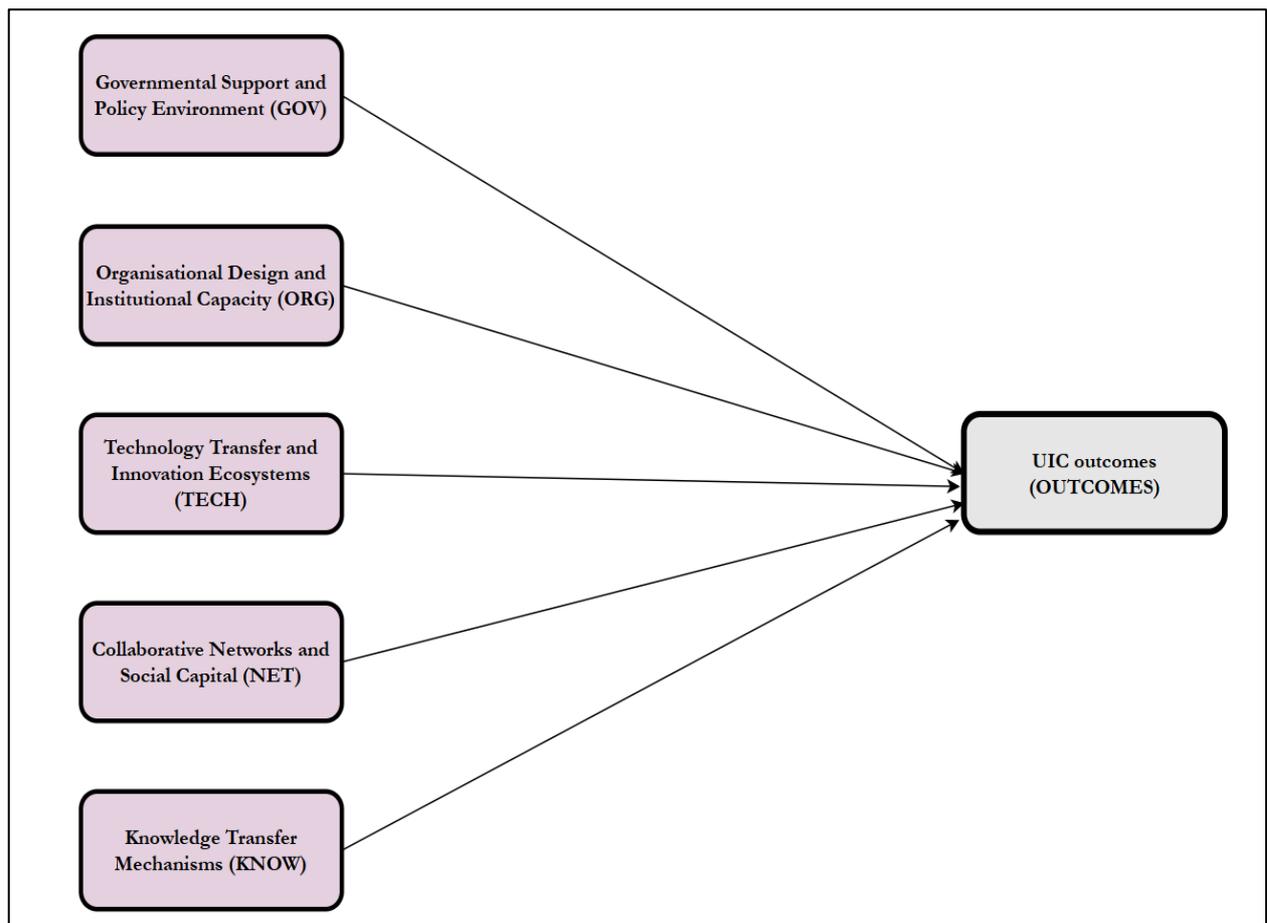


Figure 1: *Conceptual framework underpinning this study*

Sampling procedure and sample size

The target population comprised registered and candidate professionals across key built environment disciplines in South Africa. Membership data were obtained from the official annual reports of relevant regulatory bodies, including ECSA (Engineering Council of South Africa), SACQSP (the South African Council for the Quantity Surveying Profession), SACAP

(the South African Council for the Architectural Profession) and SACPCMP (the South African Council for the Project and Construction Management Professions). This approach ensured that all qualified and pre-qualified professionals were eligible to participate. To determine an appropriate sample size, Yamane's (1967) formula was applied using a known population of 40 015 professionals. With a 7% margin of error, a sample size of 220 was calculated. The survey instrument was distributed electronically via Google Forms, targeting professionals with demonstrable knowledge and experience in university-industry engagement. A total of 204 valid responses were received, resulting in a 92% response rate, which exceeds the generally accepted minimum for SEM (structural equation modelling) studies. The high response rate also enhanced the statistical power and generalisability of the study findings. A purposive sampling strategy was employed by targeting only registered and candidate professionals likely to have had exposure to UIC. Specifically, participants were selected from membership lists of relevant professional councils and the survey included screening questions to ensure respondents had direct or indirect experience with UIC activities such as joint research, internships, consultancy, or technology transfer projects. While some candidate professionals may have had limited exposure, only those who indicated familiarity with UIC practices were included in the analysis, ensuring that all respondents could provide informed insights.

Survey instrument design

To develop a suitable survey instrument for this study, we conducted a thorough review of relevant literature to identify the key factors influencing UIC in the built environment sector. The design of the instrument was guided by two primary objectives: first, to ensure that it demonstrated sufficient reliability and validity; and second, to keep the instrument concise and practical so that it would be easy for respondents to complete within a reasonable amount of time. The final questionnaire was divided into four main sections. The first section gathered demographic and professional background information from participants. The second section focused on the potential drivers of UIC and consisted of 21 items organised under five major constructs: governmental support and policy environment (GOV), organisational design and institutional capacity (ORG), technology transfer and innovation ecosystems (TECH), collaborative networks and social capital (NET), and knowledge transfer mechanisms (KNOW). All items were rated on a 5-point Likert scale ranging from 1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree, and 5 = strongly agree. To provide insight into

how the constructs were operationalised in the survey, a few representative items are presented below:

- H1 – Collaborative Networks and Social Capital (NET): ‘Our institution maintains strong formal partnerships with industry’.
- H2 – Governmental Support and Policy Environment (GOV): ‘National policies effectively promote partnerships between universities and industries’.
- H3 – Knowledge Transfer Mechanisms (KNOW): ‘Postgraduate students are co-supervised by both university and industry experts’.
- H4 – Organisational Design and Institutional Capacity (ORG): ‘Collaboration efforts address historical inequalities and promote inclusion’.
- H5 – Technology Transfer and Innovation Ecosystems (TECH): ‘Technology transfer offices help bring university research to market’.

The third section of the questionnaire addressed the perceived outcomes of UIC. This section included four reflective indicators designed to capture the broader impacts of collaboration, such as innovation and creativity (INN), skills development and graduate employability (SKL), knowledge creation and transfer (KCT), and research impact on local industry (RIL). These outcome variables were aligned with the study’s conceptual framework to ensure coherence in analysis. The instrument was pilot tested to confirm clarity, relevance and contextual appropriateness for professionals within the South African built environment sector. All items and constructs were designed to support the application of PLS-SEM (partial least squares equation modelling), which was used to assess the reliability, validity and structural relationships among variables in the final analysis.

Analysis of data

Data analysis was conducted in a structured and sequential manner to ensure the accuracy and reliability of findings. Initially, descriptive statistical techniques were applied using SPSS (Version 25) to screen for missing values, detect outliers, and evaluate key assumptions of multivariate analysis, such as normality and common method variance. To explore the relationships between the latent constructs and to test the hypothesised model, PLS-SEM was employed using SmartPLS 4. This method was selected due to its robustness in handling complex models, its suitability for exploratory research and its ability to accommodate both reflective and formative measurement models (Cheah et al., 2024). PLS-SEM also enables

simultaneous estimation of the measurement and structural models, allowing for detailed insights into construct reliability and the strength of interrelationships within the proposed theoretical framework (Hair et al., 2019). Before evaluating the structural paths, the measurement model was rigorously assessed for reliability and validity. Internal consistency reliability was confirmed through CR (composite reliability), with all constructs exceeding the recommended threshold of 0.70. Convergent validity was examined using AVE (the average variance extracted), and all values surpassed the minimum criterion of 0.50, suggesting that the indicators adequately represented their respective latent constructs. In addition, Cronbach's alpha values for all constructs were above 0.70, further supporting internal consistency. Discriminant validity was assessed using both the Fornell-Larcker criterion and the HTMT (heterotrait-monotrait) ratio. These methods confirmed that the constructs were sufficiently distinct from one another. The structural model was then analysed to test the relationships between the exogenous drivers (government support, organisational design, collaborative networks, knowledge transfer mechanisms and technology transfer) and the endogenous outcomes (innovation, graduate employability, research impact and knowledge transfer). To assess the significance of the hypothesised paths, a non-parametric bootstrapping procedure with 5 000 subsamples was performed. This procedure provided robust standard error estimates and confidence intervals for the path coefficients, enhancing the reliability and interpretability of the model outcomes.

Results

Background information of the respondents

The sample in this study was broadly representative of South Africa's built environment sector, encompassing professionals from key disciplines such as engineering, quantity surveying, construction management and architecture. The distribution of respondents across sectors – construction industry (41.7%), higher education institutions (36.3%), and government establishments (22.1%) – aligns with the general workforce composition, providing confidence in the relevance of the findings. The mix of professional experience, with nearly half having 1 to 5 years and over a third having 6 to 10 years, indicates that the results primarily reflect early- to mid-career perspectives. Nevertheless, the study acknowledges that certain groups, such as senior professionals with more than 20 years of experience or smaller sectors within the built environment, were under-represented. Expanding the research to include these groups in future

studies would enhance comparability, generalisability, and provide additional insights into the drivers of university-industry collaboration across the full spectrum of professionals.

Measurement model evaluation

The measurement model was evaluated using tests for convergent and discriminant validity. Convergent validity was established through the examination of item reliability, CR and AVE. As recommended by Hair et al. (2019), item loadings above 0.70 were considered acceptable. Accordingly, only items with sufficient loading values were retained in the analysis. The survey instrument was developed based on established literature on UIC, prior validated scales, and expert input from industry and academic stakeholders. Items such as GOV3, ORG1, ORG4, TECH2 and NET2 were excluded from the final model due to low factor loadings (<0.70); however, the remaining items adequately captured the constructs of interest, ensuring the model reflected the key drivers of UIC in South Africa's built environment sector. Table 2 presents the final measurement model, showing that all retained items loaded strongly onto their respective constructs. Composite reliability values for all constructs exceeded the recommended threshold of 0.70, ranging from 0.709 to 0.860, while the AVEs were all above the 0.50 benchmark (Afthanorhan et al., 2021), indicating satisfactory internal consistency and convergent validity across all constructs.

Discriminant validity was assessed using the Fornell–Larcker criterion, which requires that the square root of each construct's AVE be greater than the highest correlation with any other construct (Hair et al., 2019). As shown in Table 3, all diagonal values were higher than the corresponding off-diagonal values in their rows and columns, confirming that each construct shared more variance with its own indicators than with other constructs. This demonstrates adequate discriminant validity. The blindfolding procedure was employed to assess the predictive relevance of the structural model using the Stone-Geisser Q^2 statistic. As presented in Table 4, all endogenous constructs yielded Q^2 values greater than zero, thereby confirming that the model possesses acceptable predictive relevance. Table 5 and Figure 2 illustrate the influence of various drivers – such as knowledge transfer mechanisms, governmental support, organisational design, technology transfer and collaborative networks – on key outcomes including innovation, knowledge generation, impactful research, addressing demand-supply gaps and skill enhancement. The UIC construct explains about 51.2% of the variance in these outcome variables, emphasising its crucial role in shaping these results.

Table 2: *Measurement model results for retained constructs and items*

Constructs	Items	Loading	Composite Reliability	Average Variance Extracted (AVE)
Governmental Support and Policy Environment (GOV)	GOV1	0.778	0.743	0.653
	GOV2	0.838		
	GOV4	0.807		
Organisational Design and Institutional Capacity (ORG)	ORG2	0.931	0.709	0.663
	ORG3	0.677		
Technology Transfer and Innovation Ecosystems (TECH)	TECH1	0.825	0.833	0.660
	TECH3	0.769		
	TECH4	0.813		
Collaborative Networks and Social Capital (NET)	TECH5	0.842	0.744	0.580
	NET1	0.770		
	NET3	0.865		
Knowledge Transfer Mechanisms (KNOW)	NET4	0.631	0.846	0.679
	KNOW1	0.830		
	KNOW2	0.791		
UIC (university-industry collaboration) Outcomes	KNOW3	0.841	0.860	0.700
	KNOW4	0.832		
	OUTCOME 1	0.837		
	OUTCOME 2	0.848		
	OUTCOME 3	0.853		
	OUTCOME 4	0.808		

Note(s): GOV1 = There is sufficient government funding that positively supports UIC; GOV2 = Government policies are supportive of UIC initiatives; GOV4 = Government provides incentives that enhance university-industry collaboration; ORG2 = My organisation has dedicated units or personnel responsible for managing UIC; ORG3 = Roles and responsibilities related to UIC are clearly defined within the organisation; TECH1 = The university provides adequate technical resources that benefit industry partners; TECH3 = The technology developed through research is commercially viable for industry application; TECH4 = There is a clear mechanism in place for licensing university inventions; TECH5 = The university offers support for scaling innovations through industrial partnerships; NET1 = The university is part of an active and vibrant university-industry collaboration ecosystem; NET3 = There are regular forums, meetings, or events that promote engagement with industry; NET4 = Professional networks play a significant role in enhancing the effectiveness of UIC; KNOW1 = Knowledge generated from research is easily accessible to industry partners; KNOW2 = My institution shares research findings with industry through trainings, workshops, or seminars; KNOW3 = There is a structured platform for idea exchange between university and industry; KNOW4 = Research outputs are often tailored to meet the practical needs of industry stakeholders.

Table 3: *Assessment of convergent and discriminant validity using the Fornell–Larcker Criterion*

	Collaborative Networks and Social Capital	Governmental Support and Policy Environment	Knowledge Transfer Mechanisms	Organisational Design and Institutional Capacity	Technology Transfer and Innovation Ecosystems	University-Industry Collaboration Outcomes
Collaborative Networks and Social Capital	0.762					
Governmental Support and Policy Environment	-0.156	0.808				
Knowledge Transfer Mechanisms	0.150	-0.091	0.824			
Organisational Design and Institutional Capacity	0.010	0.054	0.092	0.814		
Technology Transfer and Innovation Ecosystems	-0.012	-0.116	0.010	-0.100	0.812	
University-Industry Collaboration Outcomes	0.167	0.292	0.386	0.185	0.405	0.837

Table 4: Assessment of predictive relevance (Q^2) using the blindfolding procedure

Construct	SSO	SSE	$Q^2 (= 1-SSE/SSO)$
Collaborative Networks and Social Capital	360.000	236.400	0.344
Governmental Support and Policy Environment	360.000	239.040	0.336
Knowledge Transfer Mechanisms	1 200.000	696.000	0.420
Organisational Design and Institutional Capacity	540.000	495.000	0.083
Technology Transfer and Innovation Ecosystems	900.000	549.000	0.390
University-Industry Collaboration Outcomes	3 900.000	2 650.040	0.321

Table 5: Coefficient of determination (R^2) and adjusted R^2 values for outcome variables

	R^2	R^2 adjusted
Outcome	0.512	0.500
University-Industry Collaboration Outcomes	1.000	0.999

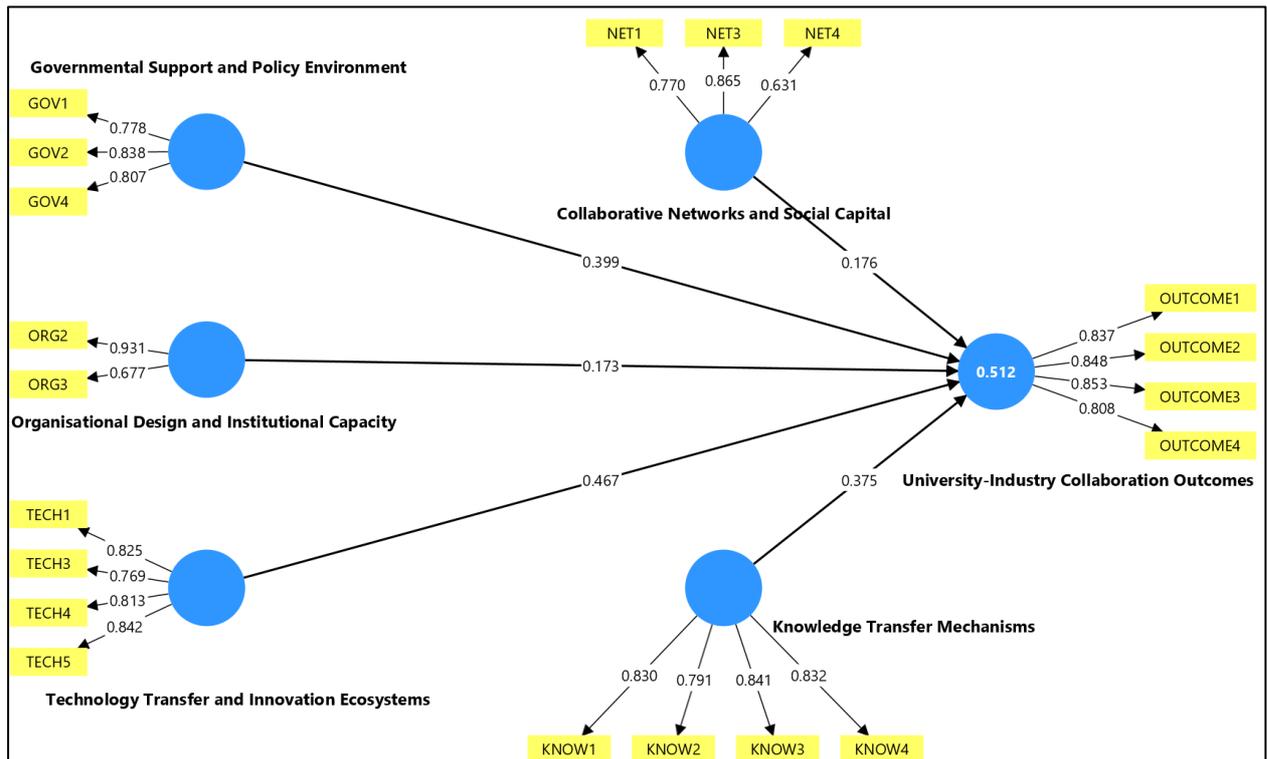


Figure 2: Measurement model of factors influencing university-industry collaboration outcomes

Structural model evaluation

Table 6 and Figure 3 present the results of the hypothesis testing, showing that all five proposed relationships in the model are supported by the statistical analysis. Each exogenous variable demonstrated a significant positive effect on university-industry collaboration outcomes, as reflected by path coefficients ranging from 0.173 to 0.467, t-statistics above 2.7, and *p*-values below 0.01. Among these drivers, H5 (technology transfer and innovation ecosystems) had the strongest impact ($\beta = 0.467$), followed by H2 (governmental support and policy environment, $\beta = 0.399$) and H3 (knowledge transfer mechanisms, $\beta = 0.375$). These results highlight the critical role of these factors in promoting successful collaboration between universities and industry, thereby validating the conceptual framework.

Table 6: Hypothesis testing results for drivers of university-industry collaboration outcomes

Hypothesis		Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P-values	Decision
H1	Collaborative Networks and Social Capital → University-Industry Collaboration Outcomes	0.176	0.174	0.065	2.729	0.006	Supported
H2	Governmental Support and Policy Environment → University-Industry Collaboration Outcomes	0.399	0.397	0.050	8.002	0.000	Supported
H3	Knowledge Transfer Mechanisms → University-Industry Collaboration Outcomes	0.375	0.374	0.047	7.933	0.000	Supported
H4	Organisational Design and Institutional Capacity → University-Industry Collaboration Outcomes	0.173	0.174	0.049	3.552	0.000	Supported
H5	Technology Transfer and Innovation Ecosystems → University-Industry Collaboration Outcomes	0.467	0.464	0.044	10.611	0.000	Supported

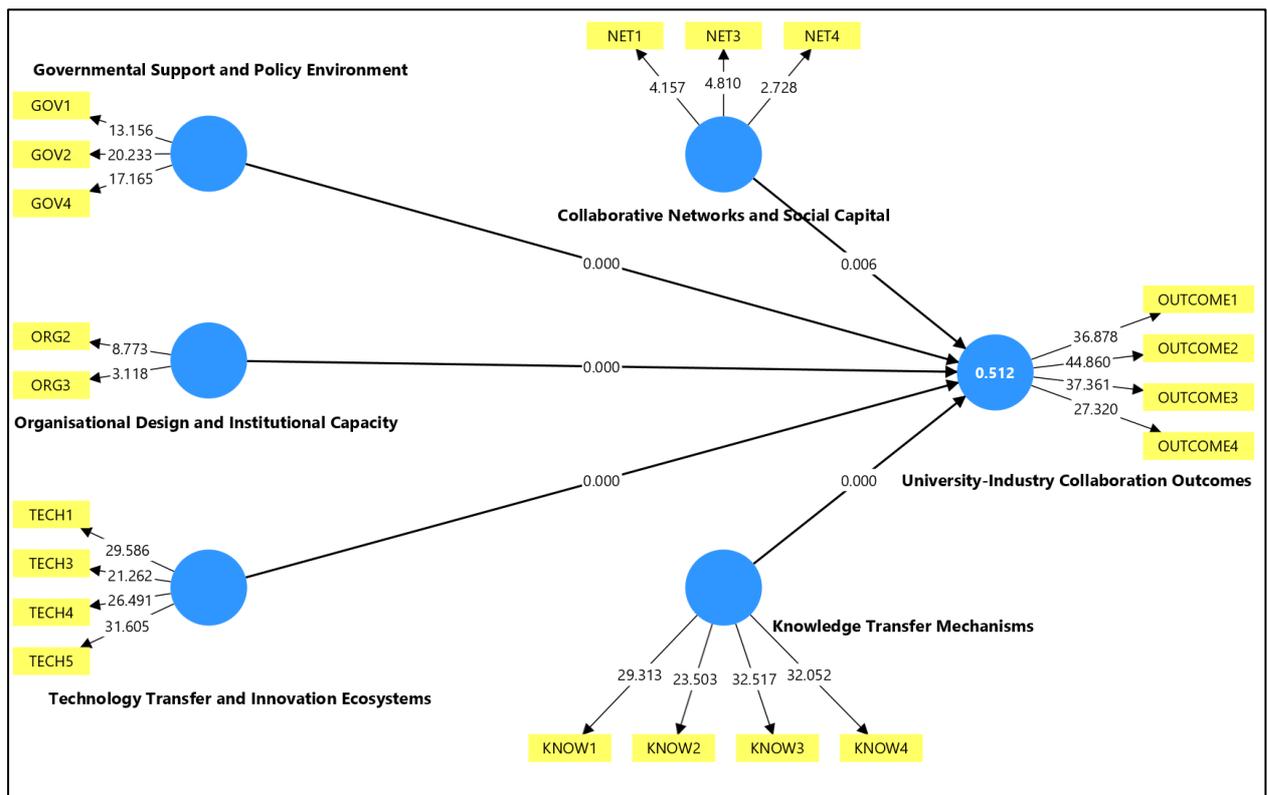


Figure 3: Structural model of factors influencing university-industry collaboration outcomes

Discussion

The findings from this study reveal that technology transfer and innovation ecosystems (TECH) exert the most substantial influence on UIC outcomes, with a path coefficient ($\beta = 0.467, p < 0.001$). This confirms H5 and underscores the importance of robust innovation systems, knowledge commercialisation processes and collaborative research infrastructures. The strong significance of TECH in the model demonstrates that the causal relationship between innovation support structures and collaboration outcomes is not only statistically valid but central to understanding UIC in South Africa's built environment sector. These findings are consistent with the global literature emphasising the role of TTOs (technology transfer offices), incubators and shared R&D facilities as vital interfaces between academia and industry. For example, Taxt et al. (2022) found that structured innovation ecosystems in Norwegian universities greatly enhanced spin-off creation and knowledge flow. Similarly, Zhuang et al. (2025) documented how strong national innovation frameworks in Singapore and South Korea catalysed university-industry partnerships. In South Africa, while institutions like Stellenbosch University and the University of Cape Town have established knowledge commercialisation frameworks, many others face resource constraints, thus limiting scalability (Stofberg, 2019). The model results substantiate these observations, showing that the presence or absence of functional innovation infrastructures directly drives collaboration outcomes. The South African government's push toward localisation and indigenous innovation through initiatives like the Technology Innovation Agency further supports this dynamic. The fact that TECH emerged as the strongest predictor highlights that co-investment in innovation infrastructure and institutionalised technology transfer processes is essential for UIC to thrive, addressing prior research gaps that emphasise structural constraints in emerging economies (Aliu & Aigbavboa, 2021).

This study also confirms H2 (Hypothesis 2), proposing that governmental support and policy environment (GSPE) significantly influence UIC outcomes. With a strong path coefficient ($\beta = 0.399, p < 0.001$), GSPE emerged as the second most significant predictor, reinforcing the quantitative evidence for the government's role in orchestrating and sustaining collaborative ecosystems. Indicators such as government funding supporting UIC, national policies promoting university-industry partnerships and sector-specific initiatives were included in the model. The PLS-SEM results directly support the high-level interpretation that government acts as a critical catalyst in the 'triple helix' of university-industry-government relations (Etzkowitz and Leydesdorff, 2000). In South Korea, well-designed national

innovation systems have similarly catalysed industry participation in academic research through incentives, grants, and targeted regional policies (Lee et al., 2017). In the South African context, the significant coefficient corroborates Petersen and Kruss (2019), highlighting the government's dual mandate to stimulate innovation while addressing socio-economic inequities. Despite fragmented funding mechanisms and policy gaps, the empirical evidence from this study indicates that well-aligned governmental initiatives play a transformative role in enhancing UIC. The focus on localised relevance resonates with current innovation policies, such as the White Paper on Science, Technology and Innovation (DST, 2019), while contrasting with low-income contexts where government involvement may be weakened by instability or underfunding (Mutongoza, 2025).

The third hypothesis (H3) was supported, with knowledge transfer mechanisms (KTM) showing a statistically significant path coefficient ($\beta = 0.375$, $p < 0.001$). The construct was measured through indicators such as joint research projects, postgraduate co-supervision, knowledge-sharing workshops and staff exchanges. The PLS-SEM findings empirically confirm that these structured mechanisms significantly enhance UIC outcomes, providing a quantitative foundation for the high-level argument that formalised knowledge-sharing is critical. Joint research projects create shared goals and mutual investment in outcomes, while postgraduate co-supervision integrates academic rigour with practical insight, often linked to sustainable innovation (Aliu et al., 2005). This aligns with Čudić et al. (2022), who found that formalised knowledge-sharing mechanisms enhance UIC effectiveness more than informal exchanges. Similarly, Azman et al. (2019) reported that institutionalised knowledge-sharing events in Malaysian universities improved technology commercialisation and innovation outputs. The positive result for H3 in South Africa suggests that structured knowledge co-creation remains foundational in emerging economies, particularly where historical divides have hindered trust. The PLS-SEM model thus provides strong empirical support for these conceptual insights.

Although hypotheses H1 and H4 were supported with lower path coefficients ($\beta = 0.176$ and $\beta = 0.173$ respectively), the results indicate that organisational design and collaborative networks are influential but not dominant drivers of UIC in South Africa. H1 proposed that organisational design positively influences UIC outcomes, measured via indicators such as clear collaboration procedures and inclusion initiatives. The PLS-SEM results confirm that internal governance and operational frameworks matter, though historical mistrust and

bureaucratic inertia moderate their impact (Petersen & Kruss, 2019). H4 posited that collaborative networks positively affect UIC outcomes, assessed through formal partnerships, community engagement and inclusion of disadvantaged institutions. The model shows that networks contribute to collaboration but with moderate strength, reflecting South Africa's fragmented R&D system compared to the dense networks in Germany or Japan (Brennecke and Rank, 2015; Bergenholtz and Waldstrøm, 2011). These empirical results support the conceptual argument that networks and organisational alignment are necessary, but they require complementary knowledge-sharing mechanisms and institutional support to drive robust UIC outcomes.

R^2 (the coefficient of determination) for the endogenous variable in this study was 0.512, indicating that approximately 51.2% of the variance in UIC outcomes is explained collectively by the five exogenous constructs: governmental support and policy environment, collaborative networks and social capital, organisational design and institutional capacity, technology transfer and innovation ecosystems, and knowledge transfer mechanisms. This represents a moderate to substantial effect size, particularly notable in the social sciences, where complex, interrelated factors often influence outcomes (Hair et al., 2019). The R^2 value affirms the model's explanatory strength and supports its validity in capturing key drivers of successful UIC within South Africa's built environment sector. Comparative studies show varied R^2 levels across different regions and sectors. For instance, Čudić et al. (2022), in a PLS-SEM study across EU and Western Balkan countries, reported a high R^2 of 0.827. Also, Kamal et al. (2024) found a more modest R^2 of 0.481 in their investigation of UIC drivers in Bangladesh, where knowledge transfer mechanisms, governmental support, organisational design, technology transfer and collaborative networks played central roles. The R^2 of 0.512 found in this study places South Africa's UIC discourse in a relatively strong position. However, it also indicates that nearly half of the variance remains unaccounted for, highlighting the need for future research to explore additional moderating or mediating variables. These may include trust, regulatory coherence, digital infrastructure, or historical inequalities in higher education, factors particularly relevant in the Global South. Longitudinal studies could also provide insights into how these relationships evolve over time.

Implications

From a practical standpoint, the results emphasise the strong influence of knowledge transfer mechanisms (H3, $\beta = 0.375$, $p < 0.001$) and technology ecosystems (H5, $\beta = 0.467$, $p < 0.001$) on effective collaboration between universities and industry. These path coefficients indicate that structured knowledge-sharing activities and well-developed innovation infrastructures are statistically the most critical drivers of UIC outcomes in South Africa. This implies that when institutions actively invest in tools like knowledge hubs, intellectual property support offices and innovation accelerators, their ability to form sustainable partnerships with industry significantly improves. Some South African universities have already taken steps in this direction, creating technology transfer offices and innovation laboratories that connect academia with real-world construction and engineering problems. However, such structures are not consistently available across the higher education space. Many institutions, especially those serving historically marginalised communities, still lack the infrastructure or support to manage knowledge exchange processes effectively. The model's findings reinforce the need for targeted interventions to expand these capabilities, aligning with earlier observations that gaps in innovation infrastructure and institutional capacity limit UIC effectiveness.

Theoretically, this study reinforces the importance of institutional design (H1, $\beta = 0.176$, $p < 0.001$) and ecosystem readiness (TECH, H5) in driving meaningful collaboration. Although H1 showed a weaker effect, it confirms that internal governance and organisational procedures are necessary foundations for collaboration, particularly when coupled with stronger drivers such as TECH and GSPE. The study contributes to UIC literature by validating a context-specific model that considers the dynamics of South Africa's built environment and the unique challenges faced in emerging economies. By demonstrating differential weights among the five constructs, the PLS-SEM results provide a nuanced understanding of which drivers matter most, directly addressing gaps in prior research where all factors were often treated as equally important. The inclusion of predictive relevance measures such as the Stone-Geisser Q^2 further confirms the robustness of the structural model, offering a useful framework for researchers seeking to study collaboration in similar settings. Overall, the findings illustrate that collaboration is a function of measurable, interacting constructs rather than solely goodwill or policy mandates, strengthening the causal argument laid out in the hypotheses.

From a societal perspective, the study reveals that stronger UIC could play a transformative role in addressing urgent challenges in graduate unemployment, infrastructure development

and innovation-led economic recovery. The model shows that outcomes such as skill enhancement, research output, and workforce readiness are significantly explained by the combined effect of TECH, KTM and GSPE, highlighting that these structural and policy inputs have measurable societal implications. Beyond high-level policy or institutional intent, the quality and consistency of collaboration infrastructure directly impact graduate readiness and institutional contribution to societal progress. The relatively weaker impact of organisational design and collaborative networks (H1 and H4) points to systemic issues where some universities remain poorly equipped structurally and administratively to engage with industry at the scale or speed required. This aligns with earlier gaps identified in the introduction regarding fragmented institutional capacity, and highlights opportunities for future interventions. Addressing this gap is essential not only for academic reform but for national development, as more agile, industry-aligned institutions are better positioned to produce graduates capable of contributing to infrastructure resilience, housing delivery, and sustainable urbanisation.

Limitations and future research

While this study offers valuable insights into the drivers and outcomes of UIC within South Africa's built environment sector, several limitations point to opportunities for future research. Firstly, the study was geographically limited to the Gauteng province. Although Gauteng is a central hub for industry and higher education, its economic and institutional context may not reflect the broader national context. Future research should expand to include other provinces such as KwaZulu-Natal, and the Western and Eastern Cape, where regional disparities in policy implementation, resource allocation and professional networks may yield different collaboration patterns. Additionally, while the study captured a broad range of professionals across disciplines, experience levels, and sectors, certain groups – such as senior professionals with over 20 years' experience, or professionals in under-represented sub-sectors – were limited in the sample. This may influence the generalisability of the findings, and future research should aim to include these groups to enhance comparability, robustness and the overall representativeness of the analysis.

Secondly, this study captured the perspectives of registered and candidate professionals in the built environment, which is valuable for understanding practical experiences and expectations from the field. However, while the study incorporated the perspectives of academic leaders and government stakeholders, who play critical roles in shaping and

sustaining UIC initiatives, it did not include the views of students, whose experiences and employability outcomes are directly impacted by these collaborations. Future studies should adopt a more inclusive approach by capturing the voices of students to better understand how UIC translates into real-world benefits for graduates. Thirdly, the research was confined to UIC, excluding Technical and Vocational Education and Training (TVET) institutions. Given the importance of TVETs in addressing mid-level skills shortages in construction and engineering, future research should explore how UIC functions in these institutions and how partnerships might differ in structure, expectations and outcomes compared to those at universities. Lastly, this study was cross-sectional in design, providing a snapshot in time. As UICs evolve over project lifecycles and policy shifts, future longitudinal studies would be valuable in understanding the sustainability, transformation and long-term impacts of these partnerships, especially in the context of technological disruption from the 4IR.

Conclusion

This study provides valuable insights into the critical drivers underpinning effective university-industry collaboration within South Africa's built environment sector. By empirically testing five key constructs – collaborative networks and social capital (H1), governmental support and policy environment (H2), knowledge transfer mechanisms (H3), organisational design and institutional capacity (H4), and technology transfer and innovation ecosystems (H5) – the study demonstrates their relative importance in shaping UIC outcomes. Through a quantitative approach using a structured questionnaire administered to registered and candidate professionals, data were analysed using PLS-SEM to examine the relationships between these constructs. The analysis confirms that collaborative networks and social capital; governmental support and policy environment; knowledge transfer mechanisms; organisational design and institutional capacity; and technology transfer and innovation ecosystems collectively form the foundation for sustainable and impactful partnerships between academia and industry. Among these, technology transfer and innovation ecosystems (H5, $\beta = 0.467$, $p < 0.001$) emerged as the strongest driver, followed by governmental support and policy environment (H2, $\beta = 0.399$, $p < 0.001$) and knowledge transfer mechanisms (H3, $\beta = 0.375$, $p < 0.001$), reflecting a nuanced hierarchy of influence that aligns with both global literature and South African institutional realities. While collaborative networks and social capital (H1) and organisational design and institutional capacity (H4) contribute positively, their relatively lower path coefficients indicate areas where structural and relational improvements are needed.

This research extends prior UIC studies by explicitly linking PLS-SEM findings to practical, theoretical and societal implications. Robust UIC not only enhances innovation and research productivity but also strengthens the development of industry-relevant skills, bridging gaps between academic preparation and workplace readiness. The model's predictive relevance ($Q^2 > 0$) and explanatory power ($R^2 = 0.512$) confirm its utility as a framework for understanding and evaluating UIC in emerging economies, highlighting the measurable impact of well-defined constructs rather than relying solely on policy or goodwill. Policymakers, institutional leaders and industry stakeholders are encouraged to prioritise these determinants, recognising that strategic investments in collaborative networks, knowledge-sharing infrastructure, policy support, and technology transfer mechanisms can drive educational quality, economic competitiveness and sectoral resilience, particularly in the context of rapid technological change and the Fourth Industrial Revolution. Finally, while the study offers strong evidence of key drivers, it is acknowledged that certain questions – such as longitudinal impacts, student perspectives, and regional variation beyond Gauteng – remain open for future research, emphasising opportunities to refine and expand the model in subsequent studies.

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