Research Paper

Exploring Civil Engineers' Entrepreneurial Competence In South Africa

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Abstract

This study examines the entrepreneurial aptitude of civil engineers in South Africa by surveying 340 engineers from the South African Institution of Civil Engineering (SAICE). Given the economic and technological changes in the engineering sector, it is crucial to understand the entrepreneurial skills of civil engineers to encourage innovation and enhance industry competitiveness. The research was undertaken using a quantitative cross-sectional method to collect data randomly from 374 individuals among over 10,000 registered engineers, ensuring a representative sample of the larger population. The research employed a structured questionnaire to assess entrepreneurial competence in areas such as identifying opportunities, evaluating risks, managing resources, and strategic thinking. Statistical analysis is used to gauge levels of entrepreneurial skills and identify factors that impact these competencies. The outcomes reveal varied entrepreneurial capabilities among civil engineers, with strengths in opportunity recognition and resource mobilisation but challenges in risk management and strategic planning. These results emphasize the need for tailored training and development programs to enhance entrepreneurial skills in the civil engineering field. The study contributes to the discourse on the role of civil engineers as innovators in the construction industry, highlighting the significance of integrating entrepreneurial education into engineering curricula and professional development initiatives. By equipping engineers with robust entrepreneurial capabilities, the industry can navigate complexities more effectively and drive sustainable growth in South Africa.

Keywords: *Entrepreneurial competence; Civil engineers; Infrastructure development; Opportunities identification; Risk-taking; Policymakers.*

INTRODUCTION

Entrepreneurship is essential for economic growth and a better quality of life. Engineering knowledge is crucial for success. Civil engineers now must develop competencies for sustainable development and effective infrastructure management. They need to create numerical models within a defined framework, integrating insights from various fields to seize opportunities. Entrepreneurship is vital for global economic growth and job creation. In South Africa, unemployment increased from 23.5% in 1994 to 34% in 2018, particularly impacting the youth. Despite being perceived as a solution, SMEs in the country are currently failing to create jobs. Since 1994, government initiatives have aimed to foster entrepreneurship. The official unemployment rate increased from 31.9% in the fourth quarter of 2024 to 32.9% in the first quarter of 2025 (Bureau for Economic Research, 2025). Civil engineers play a crucial role in infrastructure and the economy, yet their consultancies, classified as SMEs, face fierce competition (Nyakala et al., 2022). Many engineers experience dwindling profits and consider entrepreneurship, with a few new firms enjoying rapid profit growth and staff expansion, prompting enquiries about their success factors and how to replicate such outcomes.

Research on the entrepreneurial competencies of civil engineers is scarce, underscoring the need for further study. This research aims to identify key competencies for graduates seeking

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entrepreneurial careers, emphasising the need for entrepreneurial education to enhance these skills. It also addresses the absence of government support for civil engineering entrepreneurship in South Africa. How do cultural attitudes towards entrepreneurship influence civil engineers' willingness to engage in entrepreneurial activities? Models of competency development emphasise the importance of knowledge, skills, and attitudes. Knowledge encompasses facts, while skills involve the execution of tasks and procedures. Competencies evolve through education via signification (noticing changes), legitimation (interpreting changes), and domination (responsive actions). This study improves dynamic competencies through entrepreneurship education for civil engineering students, aiding in the identification of opportunities for new SMMEs, thus addressing unemployment and fostering economic growth in South Africa. It explores competencies, experience, sector differences, barriers, program integration, career impacts, and strategies for enhancing the skills of civil engineers. This research investigates the entrepreneurial competency of civil engineers in South Africa, focusing on their skills, knowledge, attitudes towards entrepreneurship, ability to identify opportunities, creativity, and risk propensity. It is significant for policymakers, education providers, and industry stakeholders aiming to foster innovation and entrepreneurship in the infrastructure sector. Empirical evidence indicates a positive correlation between entrepreneurship education and the ambition to pursue entrepreneurial careers (Crespí et al., 2022). The study examines the varying expectations of engineering role players, graduates, and recruiters, highlighting that while not all graduates aspire to start their enterprises, unique talents can foster desirable entrepreneurial abilities (Yetisen, 2024). An individualised approach to assessing entrepreneurial inclination and encouraging the development of entrepreneurial plans is essential.

Civil engineering is vital in South Africa because it organises and maintains infrastructure, which is crucial for addressing deficiencies and promoting sustainable development. Entrepreneurial competency encompasses engineers' abilities to identify opportunities, engage in ventures, foster innovation, and generate profit. The study aims to highlight the entrepreneurial capacity of civil engineers and identify strategies to enhance their contributions to national development goals. As education levels rise, civil engineers must possess both technical and business skills (Bakkali, 2022). Incorporating business-related subjects into their curriculum and providing entrepreneurship training can help reduce unemployment and address issues such as overpopulation and slow economic growth, ultimately improving the nation's economic conditions (Alam et al., 2022).

Despite the critical role of civil engineers in infrastructure development, there is a limited understanding of their entrepreneurial skills and their impact on innovation and economic growth. This study aims to examine the entrepreneurial mindset, skills, and behaviours of civil engineers in South Africa, identify obstacles to leveraging entrepreneurial opportunities, and explore methods to enhance their entrepreneurial competence in addressing infrastructure challenges and contributing to national development objectives. The overall objective is to evaluate the entrepreneurial mindsets, skills, and behaviours of civil engineers in South Africa.

Social entrepreneurship (SE) plays a vital role in South Africa by fostering positive societal, economic, and environmental changes, which contribute to a more equitable and sustainable global community (Halaissi et al., 2024). Furthermore, SE plays a crucial role in bolstering social stability, particularly in light of the country's significant challenges. Civil engineers in South Africa play a crucial role in driving economic development, creating jobs, fostering innovation, promoting sustainability, enhancing competitiveness, and sharing knowledge. Their entrepreneurial skills can identify opportunities for sustainable development, job creation, and global market competitiveness. Enhancing their skills can attract investment in the infrastructure sector and facilitate knowledge sharing within the engineering community.

Civil engineering is a vital profession for the country's growth, with many individuals transitioning into entrepreneurship. However, the need for engineering firms has decreased as developed countries transition from industrialization to economic upliftment. In South Africa, 6.4% of engineers are self-employed, with a growing trend of entrepreneurial activity (Phofi, 2023). This research aims to explore the current state of civil engineering entrepreneurial competence in South Africa and improve it, identifying factors that influence it and aligning educational frameworks with industry needs.

LITERATURE REVIEW

Entrepreneurial skills are becoming increasingly essential for civil engineers in South Africa due to challenges such as limited budgets, rapid technological changes, and a focus on sustainability. A trend is emerging in which engineers are starting their own companies or engaging in startups, indicating a shift toward entrepreneurship. Successful engineering projects often depend on innovation and business acumen, and studies show that engineers with entrepreneurial skills are better at identifying market opportunities. The inclusion of entrepreneurship education in engineering programs is gaining recognition for its role in professional development. While technical skills are crucial, understanding business principles is vital for effective project management and leadership. Aspiring leaders and entrepreneurs can significantly benefit from developing these competencies. Engineering education fosters creativity and innovation.

Civil Engineering and Entrepreneurship

The term "entrepreneur" encompasses not only those who start businesses but also individuals who create change and recognise opportunities (Van der Westhuizen, 2017). In civil engineering, innovation and entrepreneurial competencies are essential for addressing economic challenges and service delivery backlogs. South Africa faces a shortage of civil engineering entrepreneurs, which contributes to skills shortages and service delivery issues (Yetisen, 2024). Civil engineers must develop core entrepreneurial competencies in addition to their technical skills to succeed in this evolving landscape (Wang et al., 2022). Challenges for civil engineers in South Africa include bureaucratic hurdles, high compliance costs, and a lack of entrepreneurial skills (Yetisen, 2024). Despite these obstacles, civil engineers possess strong problem-solving abilities that can facilitate entrepreneurial success (Wang et al., 2022). Enhancing industry-relevant competencies through collaboration between academia and industry is crucial (Fan et al., 2022). Entrepreneurial education can positively influence students' attitudes toward entrepreneurship, with teaching strategies such as experiential learning being particularly beneficial (Iqbal et al., 2022).

Li et al. (2023) propose various strategies to enhance entrepreneurial competence among civil engineers, including integrating entrepreneurship education into their curricula. The informal sector's contribution to the economy is also significant in this context. Research indicates that participation in entrepreneurship competitions can enhance students' entrepreneurial skills (Wang et al., 2022), and educational interventions can foster positive attitudes toward entrepreneurship (Saleh & Manjunath, 2024). Bakkali (2022) and Biney (2023) highlight project-based learning (PBL) as an effective method for developing practical skills and soft skills, which are crucial for entrepreneurial success. Professional associations play a vital role in promoting entrepreneurship and providing training in ethics and soft skills (Antonovica et al., 2023). Overall, there is a growing emphasis on entrepreneurship education within engineering disciplines in South Africa, aimed at preparing graduates to establish and manage small and medium-sized enterprises (SMEs).

Entrepreneurial Competence in Engineering

This section discusses entrepreneurial competence in engineering, particularly civil engineering, highlighting its definitions, components, and measurement methods. Recent literature emphasizes the necessity for engineers to possess both technical and nontechnical competencies, including entrepreneurial skills (Van der Westhuizen, 2017). Engineers play a crucial role in improving societal infrastructure and driving innovation; however, the literature indicates a need for experiential learning to develop these competencies. Disparities exist in the perception and measurement of entrepreneurial competence, as a significant portion of the literature concentrates on limited case studies, thereby restricting a broader understanding (Dambugolla, 2020).

Government support is vital for civil engineers, with calls for policies that provide contracts to youth entrepreneurs and financial support (Dambugolla, 2020). Government policies and funding availability heavily influence the awarded tenders in the civil engineering sector (Jiang et al., 2022). Collaboration and networking are essential for civil engineers to promote sustainable practices and enhance entrepreneurial skills (Yetisen, 2024; Kotturi et al., 2024).

Financial management remains a challenge, as many small construction companies struggle to access funding. Marketing and business development are crucial for recognizing opportunities and driving innovation (Alam et al., 2022). Legal and regulatory frameworks, such as the Engineering Profession Act and CIDB, govern civil engineering consultancies in South Africa, ensuring compliance and promoting sustainability (Li et al., 2023; Yetisen, 2024). Sustainable practices are increasingly important, with civil engineers urged to adopt green methods to address industry challenges (Sharma et al., 2022; Suguna et al., 2024). Technology and innovation play a significant role in enhancing entrepreneurial skills, particularly in a digitally enabled environment (Yetisen, 2024; Ardelean, 2021). Risk assessment and management are critical for entrepreneurial success, as civil engineers must navigate uncertainties in new ventures.

Finally, project management skills are essential for civil engineers to deliver projects that meet client expectations while managing scope, budget, and timelines (Ślósarz et al., 2022; Iqbal et al., 2022; Boskovic et al., 2020). Overall, integrating entrepreneurial competence within civil engineering is vital for fostering innovation and sustainable development in the sector.

Entrepreneurship in South Africa

In a developing country like South Africa, which has struggled with high unemployment rates in recent years, entrepreneurship is seen as a potential solution to create new job opportunities (Geza et al., 2022). However, in South Africa, most entrepreneurs fail within the first few years, often due to a lack of skill, training, and education (Aruleba & Jere, 2022). Research on engineers and entrepreneurship has revealed that most sceptics believe they have the potential to become entrepreneurs, and even those who are interested in entrepreneurship pursue it reluctantly, preferring first to gain work experience (Dorschel, 2022; Apostolopoulos et al., 2023). These sceptical beliefs are more prevalent among civil engineers than in other engineering disciplines. Furthermore, graduates from vocational fields of study often tend toward job-seeking rather than job-creating behaviour, viewing self-employment as a lesser opportunity (Barner & Brown, 2021). To foster entrepreneurial behaviour among civil engineering students in South Africa, it is necessary to identify the need to promote entrepreneurship and determine how to do so in the context of civil engineering education reform (Thukral, 2021). Additionally, we need to identify and quantify core entrepreneurial competencies, considering the design-intensive and regulated professional context of civil engineers, as well as the context of developing countries (Victar et al., 2024). Finally, the need for and potential approaches to integrating entrepreneurship education into civil engineering curricula in South Africa require exploration.

Ethical Considerations in Entrepreneurial Civil Engineering

Botha and Taljaard (2021) highlight the importance of ethical professional conduct, safety, welfare, and awareness of social and environmental factors in civil engineering. SAICE, ECSA, ACPM, SAACE, and SAAGE are national professional associations that promote these principles. They emphasise respect for societal responsibilities, an understanding of basic life quality, and a commitment to sustainability. The decisions and actions of civil engineers play a crucial role in ensuring public health and safety. They emphasise the responsibility of engineers to design practical and aesthetically pleasing solutions that meet client needs while balancing the best interests of the public, engineering employers, and the profession. Ethics are based on honesty, fairness, and reliability. Ocks and Salubi (2024) emphasise the importance of respecting and keeping confidential sensitive information when personal interests conflict with professional obligations. Iqbal et al. (2022) emphasise the importance of maintaining public trust and avoiding compromises that may harm employers, clients, and the profession.

Research Theoretical Framework

The competence-based and entrepreneurial theories form the foundation of this research's theoretical framework.

Competence-Based Theories

Derived from the Latin word "competentia," competence refers to possessing a unique ability, skill, or qualification, as well as meeting a standard that entails understanding the knowledge, skills, attitude, and values necessary to achieve acceptable performance (Montilla et al., 2023). Competence-based theories focus on competencies as the underlying qualities that determine effective performance. Three competence-based theories are human capital theory, psychological theory, and sociological theory. These theories focus on entrepreneurial drivers, such as education, personality, and the social environment (Saravanakumar, 2020), which result in the development of entrepreneurial competencies.

Entrepreneurial Theories

Competence-based theories emphasise the crucial skills and capabilities that individuals must possess and develop in their professional and personal lives for optimal performance (Ismail et al., 2023). The professional responsibility and accountability of the profession strongly influence the competence of civil engineers in South Africa, according to a study (Wijayanto & Riani, 2021). This research underscores the importance of a more comprehensive understanding of the entrepreneurial disposition among engineers, particularly in the context of job losses in the civil engineering sector. The study suggests that exploring the civil engineer's entrepreneurial competence could provide a starting point for understanding their consideration of entrepreneurship as an alternative career path.

RESEARCH METHOD

A survey strategy was employed within this positivist, quantitative study. This strategy enables the collection of standardised data from a large and representative sample, allowing for the measurement of the relationship between civil engineering and entrepreneurial competencies and the generalisation of findings to the broader population, thereby directly addressing the research aims and objectives. This research aimed to explore the entrepreneurial skills of civil engineers in South Africa using a quantitative approach. A sample size of 374 individuals was selected from over 10,000 registered engineers, ensuring a representative sample of the larger population through simple random sampling. The study focused on registered civil engineers, categorising them as entrepreneurial civil engineers in South Africa while excluding those who were not registered with

SAICE from the data collection process. This method provided precise and reliable information, allowing for a comprehensive analysis of the subject matter.

The extensive pool of registered engineers provided diverse perspectives and expertise, allowing for a generalisation of the results to the entire population. A survey was conducted to collect data on key aspects of entrepreneurial skills. The covariance matrix of unstandardized residuals, descriptive statistics, and robust fit indices provides a solid foundation for assessing entrepreneurial competence in civil entrepreneurship. These elements enhance the model, clarify data interpretation, and support the reliability and validity of findings. This thorough approach significantly enhances research strength and provides credible insights into entrepreneurial competence in this area. The questionnaire was adopted from the Universal Competency Framework (Bartram, 2005) and the EntreComp framework (Bacigalupo, 2019).

A pilot study involving 10 respondents provided valuable insights that informed a guideline for a quantitative research project aimed at exploring various factors. Although the pilot results were not included in the final project, the insights were crucial for guiding the research direction and methodology, and enhancing the reliability of future findings, as indicated by a Cronbach's alpha score of 0.82.

FINDINGS AND DISCUSSION

Table 1. Research Demographic Results.

Variable	Respondents Category	N=Counts	Respondents Percentage
Gender	Female	159	42.5%
	Male	215	57.5%
	Total	374	100.0%
Race	African	359	96.0%
	Indian	6	1.6%
	Coloured	7	1.9%
	White	2	.5%
	Total	374	100.%
Engeneering field	Construction	260	69.5%
	Geotechnical	4	1.1%
	Water resources	56	15.0%
	Structural	54	14.4%
	Total	374	100%
Sector of activity	Private	227	60.7%
	Public	147	39.3%
	Total	374	100%

The demographic data indicates a significant predominance of males in the African construction engineering sector. Among the 374 participants, 159 were females (42.5%) and 215 were males (57.5%). A remarkable 96.0% identified as African, highlighting a notable lack of diversity. In engineering disciplines, construction dominated at 69.5%, followed by water resources at 15.0%, structural engineering at 14.4%, and geotechnical engineering at just 1.1%. Employment data indicate that the private sector leads significantly, with 227 respondents (60.7%), while the public sector comprises 148 respondents (39.3%). This workforce analysis offers valuable guidance for initiatives aimed at enhancing diversity and representation in the engineering field. The findings reveal construction engineering as the favoured study area, with lower public sector representation. Addressing this disparity is crucial for achieving balanced and equitable representation in engineering, which in turn prompts further exploration of the underlying factors

contributing to this imbalance.

Factors Influencing Entrepreneurial Competence

Table 2. Factors Influencing Entrepreneurial Competence Indexing

Construct	Indicator variables	Label
Entrepreneurial Competence	I can distinguish between profitable opportunities and not so profitable opportunities	EC1
	I often set a goal but later choose to pursue a different one	EC2
	I could quickly identify three guerilla ideas to help a start-up venture	EC3
	I believe that I can grow in positive ways by dealing with difficult situations	EC4
	Project Management Entrepreneurial Skills	PME

Table 3. Descriptive Statistics of Entrepreneurial Competence of Civil Entrepreneurs

Descriptive Statistics of entrepreneurial competence of civil entrepreneurs

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
EC1	374	1.00	5.00	4.22	.93	-1.28	.126	1.33	.25
EC2	374	1.00	5.00	2.50	1.36	.38	.126	-1.15	.25
EC3	374	1.00	5.00	3.67	1.11	-.79	.126	.083	.25
EC4	374	1.00	5.00	4.45	.86	-2.02	.126	4.429	.25
Valid N (listwise)	374								

The descriptive statistics present the entrepreneurial competence of civil entrepreneurs across four competencies (EC1 to EC4), measured on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). These statistics provide interpretations of each variable.

The variable EC1 states, "I can distinguish between profitable and not-so-profitable opportunities." The mean score of 4.22 indicates a strong agreement among respondents about their ability to identify profitable opportunities. In contrast, the standard deviation of 0.93 indicates a moderate spread, with most responses clustering around the mean.

The skewness of -1.28 indicates a leftward skew, suggesting more agreement and a tail towards lower scores, while the kurtosis of 1.33 indicates a flatter distribution with fewer extreme values.

Variable EC2 stands for reads. "I often set a goal but later choose to pursue a different one." The EC2 mean score of 2.50 indicates that respondents are neutral about shifting goals, demonstrating ambivalence without a strong trend. The standard deviation of 1.36 suggests considerable variation in responses. The skewness of 0.38 indicates a slight tendency toward

disagreement, implying that not many change their goals frequently. At the same time, a kurtosis of -1.15 reveals a more peaked distribution, with most responses around the neutral score.

The statement, "I could quickly identify three guerrilla ideas to help a start-up venture," appears in the variable EC3. It has recorded a mean of 3.67, indicating respondents generally feel competent in generating creative solutions for start-ups. Additionally, the standard deviation is 1.11, indicating moderate variability in responses, with values mostly clustered around the mean. The skewness of -0.79 indicates a greater degree of agreement among respondents, with fewer strong disagreements, while a kurtosis of 0.083 suggests a normal distribution of responses.

Variable EC4 reads, "I believe that I can grow in positive ways by dealing with difficult situations." It has a mean of 4.45; this high mean indicates strong agreement, reflecting a belief in personal growth through challenges. The standard deviation is 0.86; a lower standard deviation indicates that concentrated opinions are likely to be in agreement. The skewness is -2.02, indicating a significant negative skew that suggests a majority of respondents feel positively about growth resulting from challenges. The kurtosis is 4.42, a high value that signifies numerous strong agreement scores, suggesting a shared belief among the respondents.

Overall, the findings reveal key trends in entrepreneurial competence among civil entrepreneurs. Respondents firmly believe in their ability to recognise profitable opportunities (EC 1). They also find personal growth through challenges (EC 4). They show neutrality in shifting goals (EC2), suggesting consistency in pursuits. There is agreement on generating creative ideas for start-ups (EC3), but less so than for EC1 and EC4. These insights may benefit educational programs that seek to enhance the skills and competence of civil entrepreneurs.

Table 4. Covariance Matrix of Unstandardized Residuals for Entrepreneurial Competence

Label	EC1	EC2	EC3	EC4	PME
EC1	-0.000				
EC2	-0.020	-0.000			
EC3	0.053	-0.022	0.000		
EC4	-0.044	0.029	-0.004	-0.000	
Average absolute residual = 0.0393					
Average off-diagonal absolute residual = 0.0654					

The covariance matrix indicates a perfect model fit for measures of entrepreneurial competence and entrepreneurial self-efficacy, with diagonal values of zero signifying no unexplained variations. Off-diagonal entries reveal a slight inverse relationship, particularly between EC1 and EC2, which exhibit negative covariance (Candogan et al., 2024). An average absolute standardised residual of 0.0172 suggests a good fit (Baskaran et al., 2024), while an average off-diagonal residual of 0.0287 points to some unexplained variability (Rickward, 2024). Notably, 99.99% of residuals fall between -0.1 and 0.2, underscoring the model's exceptional performance. The model effectively explains a significant portion of the variability in entrepreneurial competence measures, reinforcing confidence in the measurement tools used. Despite a satisfactory fit, the model exhibited a margin of error of 0.01%, necessitating further tests to confirm its appropriateness.

Residual covariance measures and evidence of convergent validity were within the -0.1 to +0.1 range, with values near zero indicating a satisfactory fit. Both standardized and unstandardized average absolute residuals were close to 0.00, demonstrating a minimal

discrepancy between the hypothesized model and the data. The diagnostic fit analysis affirmed an adequate model fit. To develop a suitable entrepreneurial skills framework for the construction industry, hypothesis testing was essential to ensure model fit. A combination of criteria was recommended, including incremental and absolute fit indices such as the chi-square test, comparative fit index (CFI), goodness-of-fit index (GFI), normed fit index (NFI), and non-normed fit index.

Robust Fit Indices for Entrepreneurial Competence Construct

Table 5. Robust Fit Indices for Entrepreneurial Competence Construct

Model fit indices	Threshold/values	Estimated	Comment
S-B		4.1073	
Df		2	
Chi-square (χ^2/df)	< 5 (acceptable fit); < 3 (good fit)	2.0537	Acceptable fit
Comparative Fit Index (CFI)	> 0.90 (acceptable fit); > 0.95 (good fit)	0.986	Good fit
Incremental Fit Index (IFI)	> 0.90 (acceptable fit); > 0.95 (good fit)	0.986	Good fit
Normed Fit Index (NFI)	> 0.90 (acceptable fit); > 0.95 (good fit)	0.973	Good fit
Non-Normed fit index	x ≥ 0.90 (acceptable) x≥0.95 (good fit)	0.957	Good fit
Root Mean-Square Error of Approximation (RMSEA)	≤ 0.08 (acceptable fit); ≤ 0.05 (good fit)	0.053	Acceptable fit
RMSEA 90% CI		0.000- 0.127	Acceptable fit range

The fit indices for entrepreneurial competence indicate how well the model represents the data. Table 3 shows the goodness-of-fit indices achieved through statistical analysis. The Satorra-Bentler scaled chi-square (S – Bχ2) was valued at 2.0537, within the acceptable fit range. The normed chi-square value is calculated by dividing S – Bχ2 by the degrees of freedom. The CFI, IFI, and normed fit index all had values over 0.95, indicating a satisfactory match. The RMSEA was determined to be 0.053, indicating a satisfactory model fit. Overall, the fit indices indicate a good fit with the data.

The Reliability and Construct Validity of Entrepreneurial Competence

Table 6. The Reliability and Construct Validity of Entrepreneurial Competence

Indicators	**Factor loadings**	**Cronbach's alpha**	**Reliability coefficient (Rho)**	**Internal consistency**
EC1	0.957			

Indicators	Factor loadings	Cronbach's alpha	Reliability coefficient (Rho)	Internal consistency
EC2	0.881	0.725	0.712	0.762
EC3	0.777			
EC4	0.789			

The research aimed to determine the internal consistency and reliability of the entrepreneurial competence measure using the Rho and Cronbach's alpha coefficients. According to Kline (2005), the reliability coefficient for variables should ideally range from 0 to 1.00, with values approaching 1.00 being considered acceptable. In this study, the Cronbach's alpha and reliability coefficient were found to be 0.725 and 0.712, respectively, exceeding the minimum threshold of 0.7. This indicates a strong level of internal consistency and reliability.

Factor loading, which measures the covariance and correlation between variables and the primary variable or construct, indicates the strength of the association between the variables and the primary variable or construct. A factor loading of 0.5 indicates that the latent construct accounts for 25% of the total variation in the indicator variable. To explain 50% of the variation in an indicator variable, a parameter variable or factor loading should be at least 0.5 or higher, ideally 0.7 and above. In this study, the factor loadings of the variables exceeded 0.7, indicating that over 50% of the variation in the indicator variables was accounted for. This indicates a strong association between the indicator variables and the concept of entrepreneurial ability. Therefore, the construct of entrepreneurial competence successfully met the requirements for internal reliability and construct validity.

Proposed Framework for Essential Entrepreneurship Skills

Table 7. Proposed Framework for Essential Entrepreneurship Skills

Latent construct	Indicator variables
Core entrepreneurial competence model	Opportunity assessment
	Resource leveraging
	Maintain focus yet adapt
	Resilience
	Building and using networks

The study analysed factors related to the strategic and competitive implementation of civil engineers in South Africa. The residual covariance estimate was found to be symmetrical and centred on zero, addressing challenges such as multicollinearity and excessive correlations. The cluster factor for core entrepreneurial competence was identified as 'Entrepreneurial leadership', accounting for 39.8% of the variation.

The article proposes measures to enhance the entrepreneurial competence of civil engineers in South Africa, including targeted entrepreneurship training programs, networking opportunities, regulatory reforms, innovation adoption, and the integration of entrepreneurship education into university curricula, as well as industry support mechanisms and collaboration among government agencies, academic institutions, industry associations, and professional bodies. These proposals aim to bridge the knowledge gap and equip civil engineers with the indispensable entrepreneurial

skills they need.

The Civil Engineering Foundational Entrepreneurial Skills (CEFES) competency framework is also discussed, which aims to enhance perceptual skills, self-sufficiency, and competence in civil engineers. Policy makers should use these findings to establish policy frameworks that govern professional organisations, shaping curricula and ensuring the sustainability and high-quality capabilities necessary for future tertiary education. Braga et al. (2014) argue that entrepreneurial competence profiling serves as a strategic measure for integrating practical skills into engineering education. Policy makers should implement systems that encourage individuals to adopt an entrepreneurial mindset and assist in developing technically creative ideas during in-service training.

The study examines civil engineers' perceptions of their entrepreneurial competence in South Africa and the factors that influence it. It found that civil engineers are generally unaware of their entrepreneurial competence, despite their perceived abilities. The research emphasises the importance of education and training in enhancing entrepreneurs' competence. Universities and continuing education institutions should consider incorporating civil engineering entrepreneurship into educational interventions and introducing relevant concepts and policies in undergraduate programs. The study also suggests transferring knowledge and experience from entrepreneurial engineers to non-entrepreneurs. To determine its applicability beyond South Africa, further research is necessary.

Furthermore, entrepreneurship is vital for economic growth; however, South Africa and Africa face challenges such as skill shortages, inadequate infrastructure, and limited access to financing. While educational institutions promote entrepreneurship, many teachers tend to emphasise theory over practical skills. This study examines the perspectives of civil engineers on the essential competencies required for entrepreneurship and education. Identifying specific civil engineering competencies is crucial for recognising opportunities and innovating. Although entrepreneurship education exists, it is insufficient at the tertiary level. Institutions should adopt entrepreneurial discourse and develop relevant core competencies. While global models are available, local adaptation is essential. Defining discipline-specific competencies will facilitate the development of effective training programs, as previous research on the competencies of civil engineers in South Africa is limited.

CONCLUSIONS

Creativity and innovation are not exclusive to large-scale engineering; small-scale engineering can also significantly contribute to implementing systems that consider financial constraints and aid in poverty reduction (Yetisen, 2024). Emphasising locally produced technology can help equalise technological access and potentially create jobs while expanding opportunities for accredited engineers and technologists, particularly within designated underrepresented groups. This inclusiveness aligns with South Africa's diverse population and strengthens the engineering profession, which is vital for the country's economy, urbanisation, and industrialisation. The increasing population has shifted individual roles from students to job seekers, underscoring the importance of creativity and innovation as key drivers of societal growth. Various factors influence innovative behaviour, with education playing a crucial role, depending on available resources and personal experiences (Naqvi, 2021).

The civil engineering sector has long overlooked entrepreneurship education, creating a gap in understanding entrepreneurial competencies among graduates. This neglect continues despite the need for training to boost societal well-being. Stakeholders must collaborate to develop strategies for fostering entrepreneurial ventures within civil engineering. This study highlights the essential entrepreneurial competencies that civil engineers need to strive for success. Academics

and practitioners have not thoroughly studied civil engineering entrepreneurship, despite its recognition. Questions persist about the identities and competencies of civil engineers in this evolving market.

LIMITATION AND FURTHER RESEARCH

The quantitative design of the research on civil engineers' entrepreneurial competence in South Africa may have specific limitations, such as response bias and a limited scope. These issues threaten the generalizability and applicability of the findings. To improve this, future research should adopt mixed-methods approaches, conduct longitudinal studies, focus on sector-specific investigations, explore barriers and facilitators, and compare civil engineers' entrepreneurial competence with that of related fields. This approach could enhance understanding of factors that contribute to the entrepreneurial success of civil engineers. Future research should use web questionnaires, address recruitment issues, and collaborate with universities and recent graduates. Engaging junior technologists and evaluating the roles of engineers in community projects could uncover new opportunities. Collaborating with academic institutions could enhance the inclusion of entrepreneurship in civil engineering education.

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