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Laser scanning technology for construction project delivery in developing economies: a confirmatory factor analysis of hindering factors

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Abstract

Purpose – The use of technological innovations to effectively deliver construction projects is gaining significant coverage. This study aims to assess the inhibiting factors to the utilisation of laser scanners for the delivery of construction projects in developing economies using South Africa as the study area.

Design/methodology/approach – Adopting a quantitative technique, this study elicited responses from construction professionals using a questionnaire as the instrument for data collection. A four-pronged data analysis method was used, comprising descriptive statistics, Kruskal−Wallis h-test, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).

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Findings – Findings from the study show that lack of awareness and high cost of acquisition are the barriers rated by the study's respondents the most. Also, findings from the EFA and CFA conducted showed and affirmed the significance of three constructs inhibiting factors to the utilisation of laser scanners for construction project delivery: technical hindrances, financial impediments and institutional challenges.

Practical implications – This study makes practical contributions to the discourse of using innovative technologies for effective construction project delivery by inhibiting factors to the use of laser scanners.

Originality/value – Evidence from the literature shows that no study has assessed the barriers to the utilisation of laser scanning technology for construction projects in the South African construction industry. This study strives to close this gap in the literature.

Keywords Laser scanners, Barriers, Construction, Project delivery, South Africa

Paper type Research paper

Introduction

The construction industry is saddled with the responsibility of the production of building and civil structures in the various sectors of the economy of any nation, such as property, transportation, manufacturing and energy (Berk and Bicen, 2018; Rachid *et al.*, 2019; Shang *et al.*, 2020). The industry plays a vital role in determining the degree to which efforts in investment in a resource-rich country are transformed into investment results (Jarkas, 2015; Manoharan *et al.*, 2020; Windapo and Cattell, 2013). The importance of the construction industry extends to its contribution to the socio-economic well-being of any nation. According to Mulder (2013), the industry makes provisions for employment for various categories of skilled and unskilled members of society while also contributing directly to improving the quality of life of the end-users. However, the numerous advantages and contributions of the construction industry are impeded by the prevailing challenges encountered in the delivery of construction projects. The challenges confronting the delivery of construction projects include poor-quality delivery, health and safety issues, schedule overrun, underperforming projects and cost overrun (Ikuabe and Oke, 2019; Ikuabe *et al.*, 2020a; Mustapha *et al.*, 2016; Sultan and Kajewski, 2013). It is therefore advocated that techniques and approaches that can aid in abating some of the challenges confronting the construction industry should be adopted. On this note, the uptake of technological innovations is highly encouraged.

The uptake of digital technologies for construction activities and processes has been touted to bring solace by providing solutions to problems attributed to construction project delivery (Aghimien *et al.*, 2022; Ikuabe *et al.*, 2020b). Laser scanners are an innovative technology that rescues construction processes from inefficiencies and ineffectiveness. Utica *et al.* (2017) noted that laser scanning technology enables remote detection of the morphology of a building or object through laser beams that strike the surface of the object to be detected, leaving a point as the trace. Furthermore, laser scanning is a technique of high-accuracy mapping or reality capture that uses laser beams to capture details of a section of a building project (Tang *et al.*, 2022). This is actualised through the acquisition of data in the form of point clouds projected in shapes and dimensions of objects in real space converted and represented as a collection of points in 3D digital space (Abdul Shukor *et al.*, 2015; Akanmu *et al.*, 2014; Sepasgozar *et al.*, 2014). In essence, the technology is used to specify parameters of buildings and building objects attributed to very complex shapes (Pawłowicz *et al.*, 2018). Also, laser scanning technology is used for construction project progress monitoring and dimensional compliance control (Maleek *et al.*, 2018). Hence, this enables the conformance of critical dimensional quality control of construction works, which ultimately leads to the risk reduction of late-identified errors.

Using laser scanner technology reduces the labour requirement for site layout for construction projects. Benli (2015) affirmed that using laser scanners for construction operations achieves a 50% reduction in the labour requirement. Also, a reduction in construction time is encountered when laser scanning technology is adopted for construction projects, resulting from the reduced personnel needed Utica *et al.* (2017). Deploying laser scanners for construction activities abates some inherent risks associated with project delivery (Shanbari *et al.*, 2016). This is attained by circumventing some prevailing risks attributed to human personnel task delivery. Benli (2015) outlined that quick data acquisition from laser scanning technology hinders personnel's exposure to harmful environments through time reduction. Early detection of defects in construction projects is also enhanced with laser scanning technology (Utica *et al.*, 2017). Hence, this significantly reduces or eliminates the need for reworks associated with construction projects. This is actualised by capturing the state of the building structure *in situ* with 3D point clouds. Premised on the aforementioned benefits of the technology, this study develops the research questions (*RQs*):

RQ1. What are the hindrances to using laser scanning technology for construction project delivery?

RQ2. What are the possible measures for driving the use of laser scanning technology for construction project delivery?

The study aims to identify and evaluate the drawbacks of implementing laser scanning technology for construction project delivery using a second-order multivariate statistics technique.

The delivery of construction projects in most developing countries is riddled with numerous challenges that can be overcome using laser scanning technology. Furthermore, with the outlined benefits associated with the espousal of laser scanners for construction project delivery, it is imperative to evaluate the barriers to the uptake of the technology for construction project delivery. The study's findings would provide a roadmap for relevant stakeholders in the construction industry, as well as the steps and actions needed to propel technology adoption. The study contributes significantly to the body of knowledge on the drive for inculcating innovative technologies in construction project execution. The other sections of this paper comprise a review of the extant literature on laser scanners for construction projects, methodology for the study, findings emanating from the study, discussion of findings, conclusion and recommendations.

Laser scanner for construction project delivery

The complexity of the construction of buildings and civil structures makes it pertinent to use reliable, fast and accurate monitoring systems for the conformance of safety during project execution and the subsequent maintenance of the infrastructure (Gonzalez-Jorge *et al.*, 2012; Nguyen *et al.*, 2020). According to Shanbari *et al.* (2016), two operating principles guide the use of laser scanners: phase shift laser pulse and time of flight. The phase shift pulse principle conveys a laser beam whose modulation is engaged by harmonic waves. The return of the modulating beam to the device, in conjunction with phase difference, determines the distance calculation through the difference in transmitted and received waves. While the time of flight laser principles calculates the coordinates in 3D space in the environment based on the time taken for a reflection to be received. Laser scanning technologies enable remote detection of the morphology of a building or object through laser beams that strike the surface of the object to be detected, leaving a point as the trace (Aryan *et al.*, 2021; Meadati *et al.*, 2013; Utica *et al.*, 2017).

Laser scanners are quickly gaining acceptance as a tool for 3D modelling and analysis in the construction industry (Huber *et al.*, 2010; Wu *et al.*, 2021). According to Tkac *et al.* (2018), laser scanning is a technique of reality capture or high-accuracy mapping using laser beams to speedily capture specifics of a certain section of a building project. Also, Szafranko and Pawlowicz (2017) note that data are acquired from points of clouds, which are dimensions of objects and shapes by laser scanners in real space, and subsequently converted and embodied as an assemblage of points in 3D digital space. The working principle of a laser scanner is the measurement of angles and distances between the scanned object and the device with the use of a laser beam whose reflection on the object is transmitted back to the instrument (Pawłowicz *et al.*, 2018; Ustinovichius *et al.*, 2018). The sensors are appropriately suited for capturing the geometry of infrastructure, process plants and the exterior and interior of buildings. The conventional approaches for the capture of as-built information (e.g. theodolite and measurement tape) are progressively being replaced with innovative technologies for data capture, such as laser scanners and digital cameras (Dinis *et al.*, 2020; Liu *et al.*, 2012; Sepasgozara *et al.*, 2015). The range of capabilities of laser scanners means that they can be used in various industries, such as medicine, manufacturing, architecture and engineering, just to mention a few. In building construction, Pawłowicz *et al.* (2018) note that they can be engaged in building parameter specification and characterisation of building objects attributed to complex shapes and designs. According to Gleason *et al.* (2013), scanners are deployed for the projection of high-density beams in pursuit of the exact measurement of an object at the highest level. The beams are projected from the device while the measurement is engaged in phase shifts or time of flight on its return to the source. The return time of the laser is measured by the hardware on whose assessment the distance of the physical object is ascertained in relation to the scanner. Current laser scanning technologies can send out thousands of beams per second, resulting in a point cloud of data (Liu *et al.*, 2012; Murtiyoso and Grussenmeyer, 2018).

In the construction industry, it is prevalent that building elements do not come out exactly as specified in design as a result of changes during the life span of the project or errors in construction. Laser scanners are essential in dimensional compliance control and construction project progress monitoring. Maleek, *et al.* (2018) noted that laser scanners permit decision-makers in enabling the identification of incongruities between the planned and as-built status of a project. Also, Bosche (2012) stated that contractors use laser scanners for enabling the delivery of critical dimensional quality control rapidly, comprehensively and accurately. Hence, leads to a reduction of the risk of late-identified errors that can be very costly to rectify. Furthermore, laser scanners improve the quality of the delivered facilities and enable contractors to subsequently accurately plan and design maintenance operations and future expansion of the infrastructure (Bosche, 2012; Göçer *et al.*, 2016; Lachat *et al.*, 2017). In current practices, the use of laser scanners has rapidly increased in various engineering fields within the built environment in applications such as damage detection, quality assurance, damage documentation and deformation monitoring (Brilakis *et al.*, 2010; Torok *et al.*, 2013; Guldur and Hajjar, 2014).

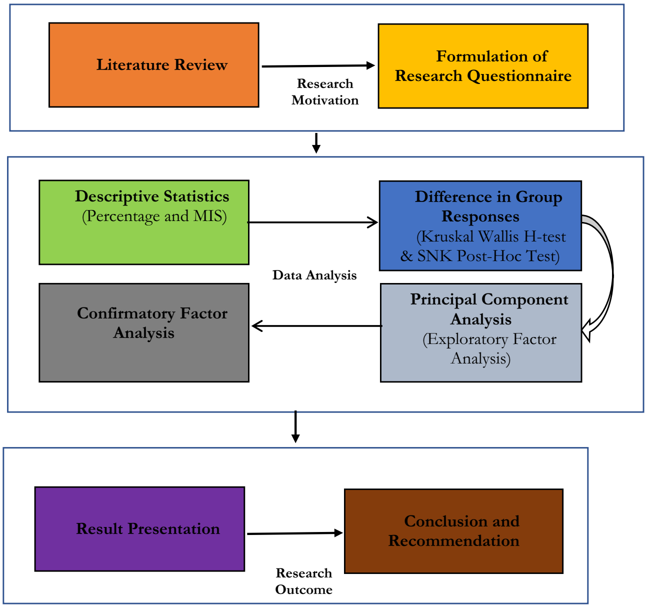
Barriers to adopting laser scanning technology for construction projects

Recognising the importance of adopting innovative and digital technologies in the delivery of construction projects, the hindering factors to the espousal of these technologies must be evaluated. For laser scanners, considering that the technology is quite a new concept in developing countries, peculiar hindering factors would be associated with its espousal (Uotila *et al.*, 2021). The resistance to change by stakeholders saddled with construction project delivery hinders the technology uptake. Royal Institution of Chartered Surveyors (RICS) (2018) stated that a key aspect of the human element pushing back the espousal of innovative technologies is the opposition to change by stakeholders. Since stakeholders are accustomed to traditional approaches to construction project execution, resistance is exhibited towards alternative approaches and techniques. Also, the cost of digital technologies has been portrayed as a significant barrier to their espousal for construction projects. Leite *et al.* (2016) opined that costs of purchase, operations and maintenance deter inculcating digital technologies for construction projects. Moreover, the fear of a long payback period resulting from investing in digital technologies can be a barrier to committing funds to propagate its purchase (Utica *et al.*, 2017). It is worthy enough to commit resources to the investment in digitalisation due to the long-term benefits. However, these accrued benefits are not usually expressed concerning financial proceeds but dwell on the social and environmental advantages of the technology. Furthermore, due to the large data generated from the application of laser scanning technology in construction delivery and management, there is a need to use computing systems with high power and capacity. Shanbari *et al.* (2016) stated that hardware and software with high-end computing capacities must handle and process large data sizes generated. This might serve as a stumbling block towards the espousal of technology. Likewise, laser scanners are susceptible to harsh environmental conditions such as humidity, rainfall and sunshine since it is mostly used outdoors.

Using innovative technologies like laser scanners requires certain knowledge and skills. However, due to the low technical competency of construction personnel and workers in handling emerging technologies, there is an urgent need to acquire skills, training and development. The lack of the requisite skills and knowledge in handling emerging technologies has challenged the uptake of the technologies (Oesterreich and Teuteberg, 2016). Also, the lack of industry standards is hindering the utilisation of digital technologies in the execution of construction projects. With the current maturity and availability of technologies, there exists a lack of standards for these technologies in the market (Oesterreich and Teuteberg, 2016). This has inhibited the drive to change the approaches to executing construction projects through innovative technologies. Furthermore, another prevailing challenge towards adopting laser scanning technology is the time spent converting from point cloud to other enabling platforms for information gathering. For example, the biggest challenge with point cloud to Building Information Modelling (BIM) conversion processes is the time-consuming process (Wang *et al.*, 2020; Qu *et al.*, 2014). In furtherance of the aforementioned challenge, data management of points cloud from various locations coupled with the scan dates can be a huge task (Qu *et al.*, 2014). With the indiscriminate nature of reality capture for point clouds, the generated models habitually comprise extraneous or provisional characteristics in the scene that would intrude with feature detection functions in the modelling process.

Methodology

The study aimed to evaluate the barriers to the utilisation of laser scanning technology in the delivery of construction projects in South Africa. Adopting a post-positivism philosophical stance, the study used a quantitative approach to eliciting data from the study's target population, which is construction professionals. The instrument for data collection was a questionnaire, which was advantageous in providing quantifiable data within a short time frame (Tan, 2011). The questionnaire comprised two sections and was self-administered by the researcher through electronic means to the target respondents. The first section focused on the demographic characteristics of the respondents. In contrast, the second section sought the respondents' views on the challenges to the espousal of laser scanners for construction projects using a five-point Likert scale. A two-pronged sampling technique was deployed for the study using convenience sampling to get respondents with expertise in digital technologies in construction and subsequently followed by a snowball sampling technique based on referrals. This led to around 137 questionnaires filled and returned by the respondents. Data analysis was carried out using percentages for the respondents' demographic information. As shown in Figure 1, the Cronbach's



Source: Authors' own work

Figure 1. Research framework

alpha test was used to determine the reliability and validity of the research instrument. An alpha value of 0.873 was given, thus indicating the reliability and validity of the research instrument since it is closer to 1.00 (Tavakol and Dennick, 2011). Mean item score was used in ranking the identified barriers to the utilisation of laser scanning technology for construction projects as rated by the respondents based on their significance. Also, the Kruskal−Wallis *h*-test (*K-W*) was deployed to ascertain the difference in responses given by the respondents on the barriers to the use of laser scanners for construction projects based on their professional designation. According to Pallant (2005), the Kruskal−Wallis *h*-test is a non-parametric test used in assessing the significant difference in the opinions of two or more distinct groups. The result of the Kruskal−Wallis *h*-test gives a chi-square and *p*-value. It is adjudged that there is no significant difference in the opinion of the groups of respondents when the *p*-value of a variable is greater than 0.05, while there is a significant difference in the opinion of the groups of respondents when the *p*-value of a variable is less than or equal to 0.05. Furthermore, the Student Newman Kauls (SNK) post hoc test was used to differentiate the mean responses of the different groups of respondents based on their professional designation. Also, the study used principal component analysis (PCA) in the conduct of exploratory factor analysis (EFA) for the determination of the factor analysis ability and unidimensionality of the barriers identified by the study, as suggested by Oke *et al.* (2021) and Ikuabe *et al.* (2022). The essence of factor analysis is the provision of insights into structured patterns, thereby simplifying the understanding of relationship patterns of the factors (Young and Pearce, 2013). The derived constructs from the EFA were further analysed to ascertain their equivalency using confirmatory factor analysis with EQation Software (EQS) version 6.4. This approach has been used in past studies to validate the derived constructs from the EFA (Aghimien *et al.*, 2023; Akinshipe *et al.*, 2024; Chen *et al.*, 2015). The analysis used a multidimensional approach which includes indexes such as Satorra−Bentler scaled chi-square ($S\text{-}B\chi^2$), Bentler comparative fit index (CFI), goodness-of-fit index (GFI), root mean square error of approximation with 95% or 90% confidence interval (RMSEA @ 95% or 90% CI), root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR). Kaplan (2009) noted that these indexes present comparative and incremental absolute fit indexes. Also, they outlay a detailed assessment of the construct's suitability with the sampled data. A subsequent evaluation was conducted to evaluate the validity and internal consistency of the constructs using the Rho coefficient and Cronbach's alpha (Bentler, 2005).

Findings and discussion

Respondents' demographic information

The demographic characteristics of the respondents show that architects and quantity surveyors made up 11% and 22% of the total respondents of the study, respectively, while construction managers, engineers and construction project managers made up 24%, 30% and 13%, respectively. For the highest educational qualification of the respondents, 59% have a bachelor's degree, 17% have a master's degree and 22% have an honour's degree. Furthermore, based on the years of professional experience, it was revealed that 34% of the total respondents have 5–9 years of professional experience, while 24% and 19% have a professional experience of 1–4 years and 10–14 years, respectively. Based on the current employment designation of the respondents, 64% are affiliated with contracting organisations, 22% with government establishments and 14% with consulting firms.

Barriers to using laser scanners for construction projects

A total of 12 barriers to the use of laser scanners for construction project execution were identified from the review of extant literature and subsequently presented to respondents for rating based on their level of significance. Table 1 shows the ranking of the identified barriers

Table 1. Barriers to the use of laser scanners for construction projects

			K-W	
Barriers	$\bar{X}$	R	X^2	Sig.
Lack of awareness	4.39	1	2.884	0.728
High capital expenditure	4.27	2	5.481	0.595
Resistance to technology adoption	4.19	3	2.927	0.376
Lack of government support	4.12	4	9.377	0.311
Lack of training	4.05	5	7.938	0.062
Lack of industry standards	4.01	6	2.274	0.028**
Demand for high computing systems	3.92	7	4.789	0.121
Cost of maintenance	3.88	8	2.003	0.729
Need for high-end computing capacities	3.76	9	4.337	0.217
Data security	3.73	10	1.094	0.082
Lack of top management support	3.70	11	4.697	0.281
Complexity of use	3.66	12	2.287	0.315
Data management	3.66	12	2.783	0.794
Profitability worries	3.61	14	3.258	0.727
Interoperability	3.53	15	5.572	0.593
Atmospheric challenges	3.48	16	5.229	0.594
Long payback period on investment	3.42	17	6.397	0.228

Note: **Significant at 0.05
Source: Authors' own work

and the result of the K-W test. From the findings, the most ranked barrier is the lack of awareness of laser scanning technology, with a mean score of 4.39; this is followed by high capital expenditure and resistance to technology adoption, with both barriers having a mean score of 4.27 and 4.19, respectively. This is followed by a lack of government support and lack of training, with mean scores of 3.80 and 3.76, respectively. The least ranked barrier is the long payback period, with a mean score of 3.42. Generally, all the identified barriers have a mean score above 3.00, which shows that they are significant barriers to the espousal of laser scanning technology for construction project delivery in South Africa. Also, the findings from the *K-W* test show no significant difference in the opinions of the respondents based on their professional designation on 16 of the total number of identified barriers. These 16 barriers have a derived *p*-value above 0.05, implying a convergent opinion on these barriers among the groups of professionals. However, there is a disparity of opinions among the professionals on the lack of industry standards since the derived *p*-value is less than 0.05. This divergence of opinions among the groups of professionals might result from the different professional mandates in delivering core professional dictates among the various groups of professionals.

Resulting from the Kruskal Wallis *h*-test conducted on the identified barriers to the use of laser scanners for construction project delivery in South Africa, which indicated a divergent opinion on one of the variables among the group of respondents (professional designation), it becomes imperative to unravel the details of the different opinions. Hence, the Student Newman Kauls (SNK) post hoc technique was used. Table 2 shows the result of the post hoc test (multiple comparisons) conducted using the SNK post hoc technique. The findings from the test indicate that the difference in opinion is shown between the two groups of respondents. The first group comprises architects and engineers with values of 2.8266 and 2.9349, respectively. The second group comprises construction managers, construction project managers and quantity surveyors with values of 3.2722, 3.3591 and 3.4011, respectively.

Exploratory factor analysis

The study used EFA in grouping the identified barriers to using laser scanners for construction project delivery into more manageable constructs. This was conducted using PCA, which adopted varimax rotation. This approach helps reduce a large number of variables into smaller sub-scales attributed to coherent patterns (Tabachnick and Fidell, 2007). Large samples are needed for reasonable outputs in EFA (Hair *et al.*, 2006), hence a

Table 2. SNK post hoc test

		Subset for alpha = 0.05	
Groups	*N*	1	2
Architects	17	2.8266	
Engineers	17	2.9349	
Construction managers	17		3.2722
Construction project managers	17		3.3591
Quantity surveyors	17		3.4011
Sig.		1.000	0.431

Notes: Means for groups in homogeneous subsets are displayed; a. Uses harmonic mean sample size = 12.000
Source: Authors' own work

total of 137 samples were used for the study. Kaiser−Meyer−Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity were deployed to determine the factorability of the data set. KMO is used in determining the factor homogeneity and ascertaining if the partial correlation of the variables is minimal (Sharma *et al.*, 2013). Table 3 outlines the KMO and Bartlett's test of the data set. A KMO value of 0.871 is presented, which is above the threshold of 0.6 used in past studies, whilst Bartlett's test of sphericity gave a value of 2,058.552 and 0.000 as the *p*-value, proving it to be significant (Pallant, 2005). Consequently, this portrays that the data set for EFA conduct is adequate factorability and suitability. Furthermore, the correlation matrix given in the output is attributed to having a value greater than or equal to 3, affirming the data set's appropriateness as showcased in past studies (Hair *et al.*, 2006; Ikuabe *et al.*, 2024).

Table 4 outlines the result of the PCA, which indicates three components whose initial eigenvalue is greater than 1. The first component possesses an eigenvalue of 8.329 and has the highest percentage of variance explained at 24.318%. This is followed by the second component with an initial eigenvalue of 3.273, while the variance explained is 20.466%. The final component has an initial eigenvalue of 1.946, and the variance explained is 17.527%. The cumulative sum of variance explained for the three components is given to be 62.311%, which is above the 50% threshold.

Table 3. KMO and Bartlett's test

Kaiser−Meyer−Olkin measure of sampling adequacy		0.871
Bartlett's test of sphericity	Approx. chi-square	2,058.552
	df	362
	Sig.	0.000

Source: Authors' own work

Table 4. Total variance explained

	Initial eigenvalues			Rotation sums of squared loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	8.329	28.287	40.523	4.664	24.318	24.318
2	3.273	9.319	41.628	3.796	20.466	44.478
3	1.946	7.715	43.553	3.321	17.527	62.311
4	0.956	6.994	50.682			
5	0.881	5.204	62.821			
6	0.873	4.839	64.226			
7	0.836	3.671	66.222			
8	0.817	3.528	71.538			
9	0.792	2.916	76.281			
10	0.783	2.494	79.281			
11	0.774	2.274	82.027			
12	0.684	1.267	85.937			
13	0.615	1.183	88.274			
14	0.537	0.936	89.539			
15	0.473	0.914	94.741			
16	0.207	0.728	99.458			
17	0.142	0.553	100.00			

Source: Authors' own work

Table 5 outlines the factor loadings resulting from the EFA conducted using PCA through varimax rotation. It is revealed that the 17 variables identified from the literature are loaded into three components after the required iterations for the analysis. The first component is attributed to having six variables with highly correlated features and factor loadings ranging from 0.881 to 0.654. This component is labelled technological hindrance. The second component comprises five variables whose factor loadings range from 0.763 to 0.503. The component is labelled financial impediments. The third component is labelled institutional challenges and possesses six variables whose factor loadings range from 0.701 to 0.533. Also, the extracted communalities of the factors are shown to be within the range of 0.529–0.886.

Confirmatory factor analysis

The result of the EFA conducted on the barriers to the utilisation of laser scanning technology for construction projects gave three constructs. This was further subjected to CFA to affirm its applicability and validity. The robust maximum likelihood was adopted due to the non-normality of the data set. This approach would make up for the non-normality of the data set (Field, 2009). The result of the fit indexes shows that the GFI and CFI gave values of 0.971 and 0.962, respectively. This was deemed a good fit since it is recommended that a good fit is attained when the value given is ≥ 0.95, while an acceptable fit is attained when the value is ≥ 0.90 (Bentler, 2005; Iacobucci, 2010). Also, for the values of SRMR and RMSEA, the values given were 0.056 and 0.064, respectively. These values were adjudged to be acceptable fit since it is recommended that a value for both SRMR and RMSEA is passed as a good fit when the value is ≤ 0.05 when it is an acceptable fit when the value is ≤ 0.08 (Bentler, 2005; Oke and Ogunsemi, 2016; Adekunle *et al.*, 2024). Furthermore, Satorra−Bentler scaled chi-square ($S\text{-}B\chi^2$) of 7.346 with 2 degrees freedom with an

Table 5. Rotated component matrix[a]

	Component			Extracted
Barriers	1	2	3	communalities
Data management	0.881			0.783
Data security	0.843			0.886
Need for high end computing capacities	0.794			0.825
Atmospheric challenges	0.711			0.775
Complexity of use	0.682			0.529
Interoperability	0.654			0.683
High capital expenditure		0.763		0.728
Cost of maintenance		0.733		0.840
Long payback period on investment		0.673		0.784
Profitability worries		0.639		0.628
Lack of industry standards		0.503		0.716
Lack of awareness			0.701	0.582
Lack of top management support			0.683	0.865
Resistance to technology adoption			0.647	0.729
Demand for high computing systems			0.623	0.714
Lack of government support			0.584	0.734
Lack of training			0.533	0.664

Notes: Extraction method: principal component analysis; a.3 components extracted
Source: Authors' own work

accompanying *p*-value of 0.000 was given for the model, thus affirming the model's adequacy (Kline, 2005; Byrne, 2006).

The assessment of the model's internal consistency was conducted with the combination of Rho alpha and Cronbach's alpha tests. Both tests are recommended to generate a more robust value of reliability for the model (Hair *et al.*, 2019). Table 6 shows that the Rho alpha and Cronbach's alpha values are 0.894 and 0.812, respectively. Thus, this portrays a good model validity since the coefficients are above 0.7 (Hair *et al.*, 2019). Furthermore, it is revealed that the values of the standardised coefficient range from 0.638 to 0.945. This indicates a good construct validity of the model as the coefficients explained are above 50% (0.5) of the total variance explained in the model. Likewise, the values of the *z*-statistics are all above 1.96, which indicates the significance of the identified barriers to the use of laser scanning technology for construction projects. The grouped factors' predictive accuracy (R^2) is close to 1.0. The coefficients of the derived R^2 are 0.784, 0.762 and 0.815, respectively. Figure 2 illustrates the correlation of the constructs making up the model, indicating that they are significant at 0.05.

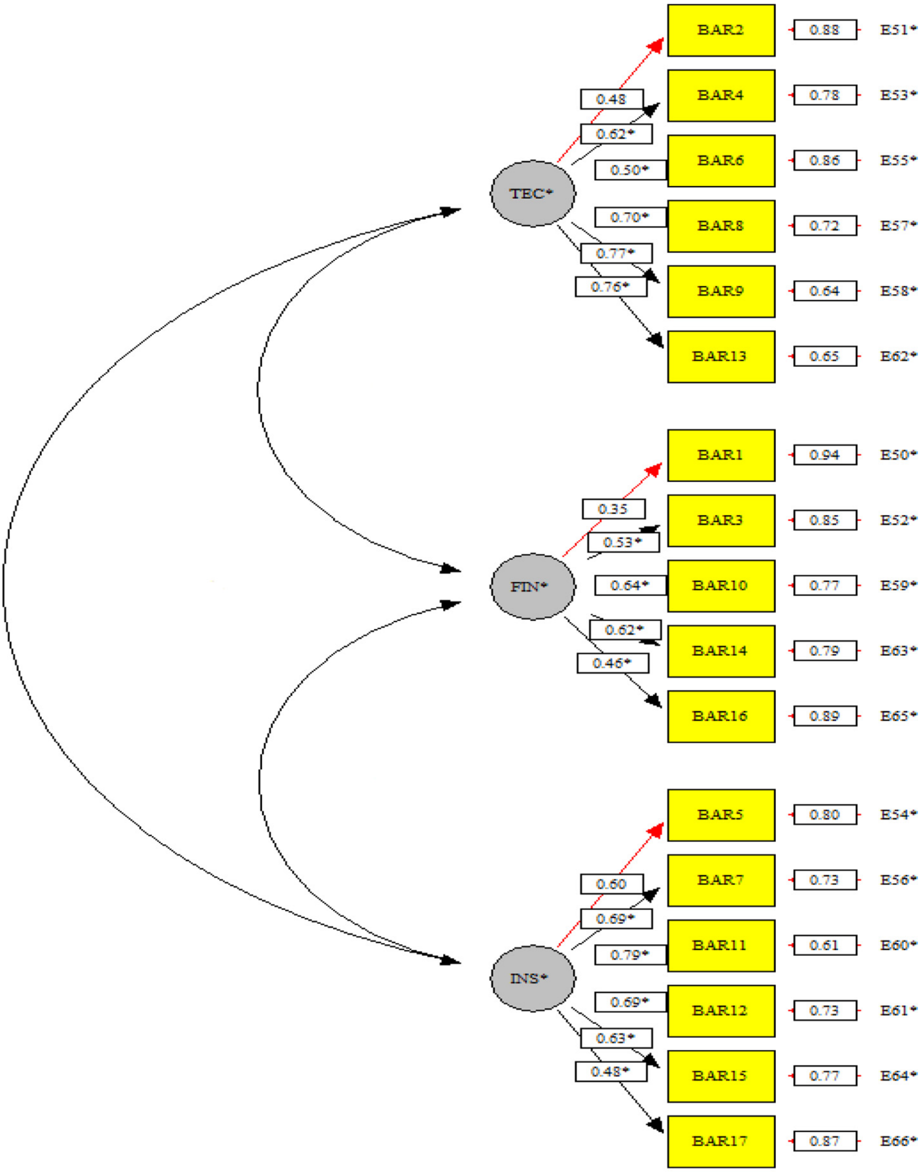
Discussion of findings

The barriers to the uptake of laser scanning technology for construction projects were assessed in this study. The analysis results showed that the most significant barrier to the espousal of technology in the South African construction industry is the lack of awareness of technology among stakeholders in the construction industry. This finding is corroborated by Leite *et al.* (2016), who noted that the emergence of innovative technologies is at a fast pace. Hence, most stakeholders are not keeping tabs on the introduction of these technologies. Moreover, there is not enough disseminated information on these innovative technologies

Table 6. CFA for hindering factors to the use of laser scanning technology

Groups	Label	Standardised coefficient (λ)	Z-statistics	R^2	Significant at 5% level?	Group R^2	Cronbach's alpha	Rho coefficient
Technical hindrances	BAR2	0.945	5.286	0.621	Yes	0.784	0.894	0.812
	BAR4	0.826	7.307	0.794	Yes			
	BAR6	0.815	10.014	0.772	Yes			
	BAR8	0.724	5.588	0.618	Yes			
	BAR9	0.709	9.132	0.709	Yes			
	BAR13	0.812	7.936	0.683	Yes			
Financial impediments	BAR1	0.803	11.026	0.813	Yes	0.762		
	BAR3	0.727	8.264	0.592	Yes			
	BAR10	0.884	9.275	0.711	Yes			
	BAR14	0.713	4.782	0.638	Yes			
	BAR16	0.842	9.381	0.784	Yes			
Institutional challenges	BAR5	0.638	8.752	0.817	Yes	0.815		
	BAR7	0.828	7.275	0.826	Yes			
	BAR11	0.897	6.391	0.639	Yes			
	BAR12	0.816	9.722	0.587	Yes			
	BAR15	0.773	7.639	0.707	Yes			
	BAR17	0.639	5.517	0.661	Yes			

Source: Authors' own work



Source: Authors' own work

Figure 2. Construct model for barriers to the use of laser scanning technology for construction projects

and their accompanying benefits when adopted for construction project delivery, leading to a lack of awareness among construction stakeholders. Also, the study shows that the high cost of procuring innovative technologies such as laser scanners hinders its uptake. This is affirmed by Shanbari *et al.* (2016), stating that the cost of purchase, installation, maintenance, upgrade and training all culminate towards posing as a barrier to the uptake of laser scanning technology for construction projects. The resistance to adopting new technologies by stakeholders in the construction industry is equally a challenge towards the uptake of technologies such as laser scanners (Dimick, 2014). This results from the belief that emerging technologies would usher in the loss of jobs, leading to foot-dragging towards using technologies such as laser scanners. Furthermore, the study's findings show that all the professionals making up the respondents of the study have a converging viewpoint regarding the identified barriers towards the uptake of laser scanning technology, except for the lack of industry standards. This might not be unconnected with the different professional dictates in delivering core professional mandates among the various groups of professionals.

Component 1 − technical hindrances. The first component resulting from the EFA is labelled as technical hindrances and is attributed to six variables, namely, data management, data security, the need for high-end computing capacities, atmospheric challenges, the complexity of use and interoperability. These findings are corroborated by Shanbari *et al.* (2016), who noted that hardware and software with high-end computing capacities are required to handle and process large data sizes generated. As a result of the nature of data generated by the use of laser scanning technology, the management of data might prove to be cumbersome (Benli, 2015; Tang *et al.*, 2022; Noruwa *et al.*, 2022; Qiu *et al.*, 2022). Also, laser scanners are susceptible to harsh environmental conditions such as humidity, rainfall and sunshine since they are mostly used outdoors. This result implies that technical hindrances significantly impede the use of laser scanning technology. Consequently, professionals and stakeholders in the construction industry are not disposed to implementing the technology since there is no clear direction for navigating the challenges.

Component 2 − financial impediments. The second component is labelled as financial impediments and consists of five items: high capital expenditure, maintenance cost, the long payback period on investment, profitability worries and lack of industry standards. The cost of digital technologies has been portrayed as a significant barrier to their espousal for construction projects. Leite *et al.* (2016) opined that costs of purchase, operations and maintenance is a deterrent to inculcating digital technologies for activities in construction projects. Moreover, the fear of a long payback period resulting from investing in digital technologies can be a barrier to committing funds to propagate its purchase (Utica *et al.*, 2017). Hence, the result shows that the financial impediments serve as a significant bottleneck in the quest to use the technology. A clear pathway of the financial implications associated with the deployment of laser scanning technology would aid in the abatement of the pitfall.

Component 3 − institutional challenges. The third component is labelled institutional challenges and consists of a lack of awareness, lack of top management support, resistance to technology adoption, demand for high computing systems, lack of government support and lack of training. This finding is supported by Royal Institution of Chartered Surveyors (RICS) (2018) by noting that a key aspect of the human element pushing back the espousal of innovative technologies is the opposition to change by stakeholders. Since stakeholders are accustomed to traditional approaches to construction project execution, resistance is exhibited towards alternative approaches and techniques. Also, the lack of the requisite skills and knowledge in handling emerging technologies has challenged the uptake of digital technologies (Oesterreich and Teuteberg, 2016; Hosamo and Hosamo, 2022; Skrzypczak *et al.*, 2022). The findings imply that the institutional problems associated with the espousal of laser scanning technology are significant barriers. Consequently, stakeholders and professionals in the construction industry should be well-equipped with advancements in innovative technologies. Relevant stakeholders and the government should lend their support towards the shift towards the deployment of such technologies.

Theoretical and practical implications. Laser scanning technology offers precision in data collection, which aids in driving optimised project execution. However, the deployment of the technology for construction projects is faced with challenges, as shown in the study as technical hindrances, financial impediments and institutional challenges. Issues bothering data security and standards create interoperability challenges across projects and teams, leading to a slow project timeline resulting from compliant risks and data processing. Also, financial constraints can pose a significant barrier to using laser scanning technology. This suggests that theoretical models of cost-benefit in construction technology call for recalibration to address some of the issues on initial costs, particularly for small and medium-sized organisations. Furthermore, there is a need to review industry standardisation and regulatory compliance, highlighting the necessity of unified protocols for data management and sharing. The current framework contributes to the bottlenecks associated with the advancement of collaborative workflows in construction project delivery, hence slowing down the development of an integrated ecosystem for driving emerging technologies.

Conclusion

The study empirically assessed the inhibitors to the espousal of laser scanning technology for project delivery in the South African construction industry. As a result of the review of extant literature, 17 variables were identified and presented to the study's respondents for the rating with a well-structured questionnaire. Data from the survey were subjected to statistical analysis, which made interesting revelations. Firstly, it was shown that the most significant barriers to the uptake of laser scanners for construction projects are lack of awareness, high capital expenditure, resistance to technology adoption and lack of government support. Furthermore, it was revealed that all the groups of professionals making up the respondents of the study all had an agreement on sixteen of the identified barriers and also had a diverging opinion on one of the barriers, which is the lack of industry standards. Furthermore, it was shown from the conduct of EFA that three constructs make up the barriers to using laser scanning technology for construction projects in South Africa. These are technical hindrances, financial impediments and institutional challenges. These developed constructs were further subjected to a CFA, which established their equivalency. The model assessment was conducted using different comparative fit indexes using a multidimensional approach. The result from the CFA affirmed the significance of the three constructs that hinder the use of laser scanning technology for construction project delivery.

Recommendations

Based on the findings from the study, it is recommended that relevant professional bodies in the construction industry embark on a massive awareness campaign that would help propagate the benefits of laser scanning technology and subsequently aid in the uptake in the delivery of construction projects. Consequently, in closing the gulf of the current expertise available, committed and intentional efforts by relevant stakeholders should be geared towards improving the knowledge base of handling emerging technologies. Also, it is encouraged that the government implement subsidy regimes to encourage the drive for the uptake of innovative technologies such as laser scanners. This would help abate the effect of the high purchase cost and investing in such technologies. This study contributes to the body of knowledge as it unravels the impeding factors to the utilisation of laser scanners for construction project delivery. Also, it serves as a solid theoretical base for further studies on the espousal of digital technologies for effective project delivery. It is important to state that this study was limited to the Gauteng province of South Africa. Other studies can be conducted in other provinces of the country for a more robust and comprehensive finding. Also, the study used a quantitative methodological approach; future studies can adopt a quantitative approach.

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