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Editorial

This editorial highlight recent five researches that delves into diverse yet impactful areas, from the factors influencing cryptocurrency adoption and precision in 3D reconstruction to advancements in dental procedures, PWM inverter design, and critical success factors in highway project management. These studies offer valuable insights and practical implications, showcasing the importance of multidisciplinary approaches in addressing current technological and infrastructural challenges.

The first paper investigates the role of personality and psychological factors in the adoption of cryptocurrency. By analysing data from 452 U.S. consumers using PLS-SEM, the research reveals that consumer innovativeness positively influences the intention to use cryptocurrency, with attitude acting as a partial mediator. Additionally, the LOHAS (Lifestyles of Health and Sustainability) lifestyle moderates this relationship, highlighting the significance of consumer characteristics in the cryptocurrency market. These findings provide both theoretical and practical implications for market strategies, emphasizing the need to consider psychological and lifestyle factors in promoting cryptocurrency adoption [1].

The second paper addresses the challenge of achieving size accuracy in 3D object reconstruction, particularly for small and detailed objects. Using Meshroom for 3D photogrammetry reconstruction and various free software tools for measurement, including MeshLab, Meshmixer, Blender, and 3D Slicer, the study evaluates the performance of these tools in terms of size accuracy. Experimental results demonstrate that Meshmixer achieves high accuracy in measuring object sizes, providing a reliable and cost-effective solution for precise 3D reconstructions. This research is significant for applications requiring detailed and accurate 3D models, such as in cultural heritage preservation and medical imaging [2].

In the field of dentistry, the third paper explores the ongoing challenges faced by endodontists in performing Root Canal Treatment (RCT). Through a survey, it was observed that the lack of precision devices leads practitioners to use supplemental methods, compromising best practices and increasing the risk of operational failures. The study highlights the benefits of touch and heat devices in ensuring stability, precision, and safety during RCT. It emphasizes the need for developing and adopting advanced heating element technology to improve the effectiveness and safety of endodontic procedures, ultimately enhancing patient outcomes [3].

The fourth paper presents a detailed analysis and practical design considerations for a pulse width modulated (PWM) inverter using an insulated gate bipolar transistor (IGBT) to drive a 0.5hp induction motor. The study outlines the power supply requirements, gate drive requirements, driver protection, and dv/dt protections necessary for successful implementation. By discussing each stage of the inverter design, from the input stage to the output load section, the paper provides valuable insights for beginners and practitioners in the field of power electronics. This research simplifies the design process and highlights the importance of understanding specific model operations and peculiarities [4].

The fifth paper investigates the critical success factors (CSFs) in highway project management in Nigeria, focusing on stakeholders' perceptions. Through a survey of 200 stakeholders, including highway engineers and quantity surveyors, the study identifies key factors influencing project success. Clear project goals, experienced design teams, proper project planning, availability of resources, and timely decision-making were found to be the most significant CSFs. Despite slight variations in opinions among stakeholders, the findings underscore the need to prioritize these factors to address issues of cost and time overruns, project abandonment, and litigation in the Nigerian construction industry. The research provides valuable insights for improving project management practices and achieving successful project outcomes [5].

These studies collectively demonstrate the importance of interdisciplinary research and innovation in addressing contemporary challenges across various fields. By integrating diverse methodologies and perspectives, researchers can develop practical solutions that enhance technological advancements, improve professional practices, and contribute to the overall progress of society.

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Editor-in-chief

Prof. Paul Andrew

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CONTENTS

Linking Consumer Innovativeness to the Cryptocurrency Intention: Moderating Effect of the LOHAS (Lifestyle of Health and Sustainability) Lifestyle

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ABSTRACT: Cryptocurrency is gaining worldwide recognition. This research examines the role of personality and psychological factors in consumers' cryptocurrency adoption behavior. 452 samples are collected from U.S consumers and the data are analyzed by PLS-SEM. The findings reveal that consumer innovativeness has a positive influence on the intention to use cryptocurrency and its impact is partially mediated by attitude. The LOHAS lifestyle moderated the influence of consumer innovativeness on the cryptocurrency intention as well as the relation of attitude with the intention. This research provides theoretical and practical implications for the cryptocurrency market.

KEYWORDS: Cryptocurrency, consumer innovativeness, LOHAS, Lifestyle of health and sustainability, attitude, intention

1. Introduction

Cryptocurrency is an innovative and rapidly growing issue in today's digital economy [1]. It is a decentralized digital currency that is based on blockchain technology that uses cryptography to secure and manage the circulation of digital coins [2], [3]. Not only the celebrities like Elon Musk and Bill Gates began to support this but also the general population realized the promise of the cryptocurrency market and began to seek an alternative financial means because it can be used to buy tangible products rather than merely for trading and investing during the pandemic [4], [5]. In 2022 the total value of cryptocurrency transactions will surpass $10 billion for the first time, which is an increase of more than 70% from 2021, and a double-digit increase in the U.S adults who possess and use cryptocurrency for payments is expected by 2023 [6].

The Natural marketing institute (NMI) coined the terminology of LOHAS (Lifestyle of health and sustainability) to define the rapid growth of global cultural trend that emphasizes the values of personal health and well-being, and environmental sustainability [7]. The LOHAS consumer segment strives to live healthy and sustainable lives and make conscious choices by considering the environmental and social impact of their consumption beyond their personal well-being [8].

Furthermore, they are early adopters who are willing to try and adopt new products and technologies considerably more than any other segment [9]. In line with this, the author pointed out that virtual grocery stores, mobile shopping, and electric transportation as LOHAS technological trends, reflecting the LOHAS consumer's technology-friendly disposition [10]. In 2022 the LOHAS consumers account for one-third of the entire U.S. adult population, and the total U.S. LOHAS configurable market is estimated to reach $472.51 billion, being expected to grow at 10% each year [11].

Whereas the majority of research on cryptocurrency has been conducted in technology, computer science, and engineering [12], the studies in marketing devoted to better understanding consumers' inner mechanism that drives to use of cryptocurrency are rare despite its potential for strategic applications of the businesses. Although limited marketing literature revealed some psychological factors (e.g., self-efficacy, emotion) as a primary motive for cryptocurrency adoption within the theory of planned behavior (TPB), to our best knowledge no research emphasized the role of consumer innovativeness in conjunction with TPB despite its importance in predicting technology acceptance [13]. Furthermore, while distinctive behavioral characteristics of the LOHAS consumers in a wide range of market

sectors such as personal health (e.g., organic food), natural lifestyle (e.g., apparel), alternative energy and transportation (e.g., electric vehicles), green building, and ecotourism are well studied [11], research on their technological behavior lacks empirical evidence despite conceptual inference on it.

Considering the academic's call for more empirical studies in marketing on cryptocurrency behavior, a better understanding is needed of what drives consumers to use cryptocurrency. Furthermore, given the growing impact of LOHAS on a wide range of consumption patterns, the examination of the role of LOHAS in cryptocurrency usage behavior will provide rich insights into the technology context. Therefore, this research addresses the following two research questions: 1) What are the roles of consumer innovativeness and attitude toward cryptocurrency in the intention to use cryptocurrency? 2) How does the impact of consumer innovativeness and attitude on cryptocurrency intention differ depending on the level of the LOHAS lifestyle?

This research provides theoretical and practical implications in several ways. First, while past research focused on affective and cognitive factors as antecedents for cryptocurrency adoption, this research additionally incorporates consumer innovativeness as a personality trait, which has been proven to be relevant for technology adoption. Beyond that, LOHAS is introduced as a new important inferential factor for cryptocurrency utilization. Second, while past literature conceptually inferred the technology enthusiastic characteristic of the LOHAS consumers, this study contributes to the body of knowledge by providing empirical evidence on their nature. Finally, businesses in the well-being and sustainability market may consider utilizing cryptocurrency as an alternative transaction method to capture the attention of LOHAS consumers.

2. Literature Review and Hypothesis Development

2.1. Consumer Innovativeness and Cryptocurrency Intention

Consumer innovativeness refers to the willingness to adapt to changes and experience new things [14]. Innovative consumers are more likely to purchase new or different products more quickly and frequently, deriving pleasure from exploring different things and trying new experiences[15], [16]. A psychological profile of innovative consumers has been described as ambiguity-tolerant, and risk-taking [17]. The importance of consumer innovativeness as a motive for technology usage has been emphasized in the literature [13]. For example, in [18], the authors found that those with a high level of IT innovativeness tend to adopt blockchain technology applications. In [19], the authors found that more innovative consumers

have a significantly higher increase in satisfaction with cryptocurrency, compared to traditional compensation types. The result shows the technological savvy of innovative consumers given that crypto-compensation is digital currency-based, which entails the use of complicated algorithms [20].

H1: Consumer innovativeness positively influences the intention to adopt cryptocurrency.

2.2. Consumer Innovativeness and Attitude toward Cryptocurrency

Attitude is defined as "the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question" and it determines the way that consumers behave in a particular way toward an object [21]. Inherent innovativeness enables people to be open to new stimuli and ideas [22], and this in turn leads people to be more readily perceived the benefits and value of adopting innovation [23]. Concerning the relationship between consumer innovativeness and attitude toward the innovative product, the author in [24] argued that novelty-seeking consumers view technical products positively, and have a stronger intrinsic motivation to acquire such products [25], [16] because they are less concerned about whether new technologies are easy to use or trustworthy for their risk and uncertainty taking predispositions [26], [27].

H2: Consumer innovativeness positively influences the attitude toward adopting cryptocurrency

2.3. Attitude and Intention to Cryptocurrency

Many scholars in the area of consumer behavior have discussed the importance of attitude in determining an individual's decisions and behavior (e.g., [28], [29]). For example, particularly in the technology utilization context, in [30] the authors found that the more one has a positive attitude toward Bitcoin, the one is more likely to intend to adopt Bitcoin. In [31] the authors also revealed that attitude has a strong positive influence on the customer's behavioral intention to use blockchain-based cryptocurrency transactions. In a similar vein, the author in [32] also revealed that attitude toward digital theft is positively associated with that behavior.

H3: Consumer attitude positively influences the intention to use cryptocurrency.

2.4. Mediating Effect of Attitude in the Relationship between Consumer Innovativeness and Intention.

Innovators perceive a value created in the innovative products and adopt new products[23]. They tend to evaluate novelty, ease of use, and functional performance of the technologies differently than the majority of late consumers, which influences their behavioral intention

[33]. For example, in [34] the authors found that eight subdomains of consumer innovativeness positively affect the intention to use and pay a price premium for drone food delivery services through a positive attitude. In [35], the authors revealed that consumer innovativeness is positively associated with the perceived financial benefits of adopting electric vehicles (EV). Similarly, in [36] the authors discovered a positive influence of consumers' innovativeness on the intention to use smartwatches through the perceived utilitarian and hedonic values.

H4: Consumer attitude mediates the relationship between consumer innovativeness and the intentions of adopting cryptocurrency.

2.4. Moderating Role of LOHAS

The LOHAS literature extensively mentioned the innovative and technology savvy characteristics of the LOHAS consumers. As early adopters who seek out the latest information, formulas, and innovative technologies [37], LOHAS consumers usually adopt and try a new product earlier than their family members or others in their social circle [38]. They not only incorporate the new product into their lifestyles but also influence their families and friends to try it [39]. They are expected to possess higher innovativeness compared to others in the later stages of adoption [40], and this may positively influence their intention to adopt an innovative technology [41].

H5a: LOHAS moderates the effect of consumer innovativeness on intention to cryptocurrency.

H5b: LOHAS moderates the effect of consumer innovativeness on attitude.

H5c: LOHAS moderates the effect of attitude on intention to cryptocurrency. Figure 1 describes the research model.
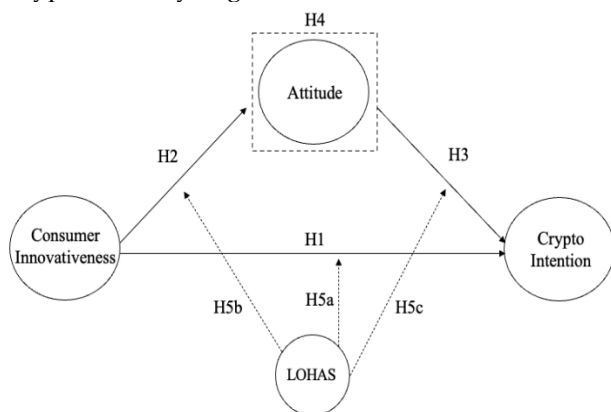

Figure 1: Research model

3. Methodology

3.1. Participants and Data Collection

Amazon Mechanical Turk (MTurk) is employed to recruit subjects of the general U.S population aged

between 18 and 65. Five hundred surveys were distributed, and four hundred fifty-two surveys were used after excluding incomplete and invalid responses. The demographic profiles of the respondents are provided in Table 3.

3.2. Measures

The constructs included in the theoretical model are consumer innovativeness, consumer attitude, cryptocurrency intention, and LOHAS. The questions for consumer innovativeness were adopted from [42] which measures the concept using a 5-point Likert scale (from 1, completely disagree, to 5, completely agree). The attitude measures were adopted from the study of [43]. The questions that measured cryptocurrency intention came from the study of [44]. The LOHAS questions were adopted from [4] which measures the level of individual well-being and sustainability orientation with 28 items.

3.3. Two Groups: LOHAS Lifestyle

We had two groups of LOHAS based on a quartile split (we dropped the two middle groups and focused on the 1st and 4th quartiles.)[45]. The low LOHAS score in the 1st quartile of the LOHAS distribution and the high LOHAS score in the 4th quartile. The 1st quartile of the LOHAS distribution (i.e., low LOHAS group) consisted of 117 participants, and they showed a lower level of belief and attitudinal and behavioral patterns for personal health and well-being and sustainability (M=74.8, $p < .001$). On the other hand, the 4th quartile (i.e., high LOHAS group) was made up of 106 participants and they indicated not only a high level of personal well-being in diverse life domains but also a strong sense of sustainability (M= 112.4, $p < .001$).

3.4. Data Analysis

Smart-PLS 3.0 was utilized to test the psychometric quality of the measurements and the path links between the latent constructs in the research model. The Smart-PLS gained popularity in marketing and management research for decades as a well-established method for the coefficient estimation of the structural model[46]. Convergent and discriminant validity were assessed, and for more rigorous reliability tests composite reliability (CR) and average variance extract (AVE) were examined thereafter. Finally, the path coefficients of the structural model were estimated using PLS-SEM.

4. Results

4.1. Measurement Model Assessment

The measurement model was evaluated based on the criteria of internal consistency, convergent validity, and discriminant validity [47], [48]. The variables' reliability was assessed using Cronbach's alpha and was found to be

satisfactory. The convergent validity of the variables was tested using factor loadings, composite reliability (CR), and average variance extracted (AVE) and the results showed that factor loadings for the items on each construct exceed the threshold of 0.70, CR values of each construct are greater than 0.7, and AVEs for all constructs are greater than the cut-off value of 0.5 [49]. This demonstrated that convergent validity is established in the complete and split two samples. The discriminant validity was evaluated based on the Heterotrait-Monotrait (HTMT) ratio of correlation on the complete and split data sets. The discriminant validity was established given that HTMT ratios are under the cut-off of 0.85 [49]. In addition, model fit was evaluated using standardized root mean square residual (SRMR) and values are less than the threshold of 0.8; 0.036 for complete data, 0.039 for the low LOHAS group, and 0.08 for high LOHAS group, indicating the satisfaction of the requirements for goodness-of-fit [50]. Table1 displays the results.

4.2. Descriptive Statistics

The sample was comprised of 282 males (62.4%) and 170 females (37.6%). Consumers aged between 26 and 35 comprised 39.2% of the sample (n= 177), followed by people aged between 36 and 45 (29.9%), and between 46 and 55 (13.3%). For education, 50% of the sample were college graduates (n=226), followed by graduate school graduates (26.8%), and high school (21.7%). Annual income less than $29,999 made up of 29.7% of the total sample, followed by $30,000 - $49,999 (25.2 %), $50,000 - $74,999 (21.9%). Concerning occupation, 73% were full-time, followed by self-employed (9.3%), and part-time (9.1%). For ethnic background, 57.1% were white/European, followed by Asian (25.9%), and native American (6.0%).

Table 1: Discriminant Validity
Heterotrait-Monotrait Ratio (HTMT)

	Complete Data			Low LOHAS			High LOHAS		
	CI	ATT	IT	CI	ATT	IT	CI	ATT	IT
CI									
ATT	0.40			0.20			0.38		
IT	0.56	0.71		0.32	0.74		0.73	0.50	

To examine the differences between the low and high LOHAS group, a nonparametric Mann-Whitney test was conducted because it does not require the normal distribution of data. Overall, the results in table 2 indicate that the values of consumer innovativeness, attitude toward cryptocurrency, and the intention to adopt cryptocurrency were significantly higher in the high LOHAS group than those in the low LOHAS group. Hence, the overall pattern showed that the high LOHAS group is more innovative, has a more positive attitude toward cryptocurrency, and is more intended to use cryptocurrency.

Table 2: Results of the Mann-Whitney Test

Construct	Low LOHAS group		High LOHAS group		p
	M	SD	M	SD	
Consumer innovativeness	2.74	0.95	4.19	0.76	0.00
Attitude	3.29	1.06	3.92	0.94	0.00
Intention	3.00	1.29	4.22	0.78	0.00

4.3. Structural Model Assessment (H1-H4)

The significance of the path coefficient was evaluated by bootstrapping method with a re-sampling of 1000 [46]. The complete model (n=452) results indicated that the effect of consumer innovativeness on the intention to adopt cryptocurrencies was positive (β = 0.303, t= 6.549, *p* <.001), supporting H1. Additionally, consumer innovativeness had positive influence on attitude toward cryptocurrency adoption (β = 0.374, t= 0.047, *p* <.001) and the attitude was also positively related to the intention to adopt cryptocurrency (β = 0.553, t= 11.907, *p* <.001), indicating the support of H2 and H3. Finally, an indirect effect of the consumer innovativeness on the crypto intention by way of the attitude was also established (β = 0.207, t= 6.230, *p* <.001), accepting H4.

To test the predictive ability of individual constructs in the model, the effect size was assessed [51]. The effect size of each exogenous construct was found to be statistically significant. Specifically, the effect of consumer innovativeness on cryptocurrency intention was medium (f^2 =0.166), the effect of consumer innovativeness on attitude was medium ((f^2 =0.162), and the effect of attitude on crypto intention was large (f^2 =0.553) [52]. The results are summarized in table 3.

Table 3: Structural Model Evaluation

	β	SE	t	P-Value	f^2
CI→INT	0.30	0.05	6.55	0.000	0.17
CI→ATT	0.37	0.05	7.87	0.000	0.16
ATT→INT	0.55	0.05	11.91	0.000	0.55
CI→ ATT →INT	0.21	0.03	6.23	0.000	N/A

4.4. Multi-Group Analysis (H5)

Two non-parametric approaches of the permutations test and Henseler's multi-group analysis (MGA) were employed to find differences across the two groups of low versus high LOHAS[53]. The MGA results indicated that there is a significant difference in the path from consumer innovativeness to cryptocurrency intention. The positive effect of consumer innovativeness on cryptocurrency intention was significant and stronger in the high LOHAS group than in the low LOHAS group (|diff| = 0.324, *p*

< .05), supporting H5(a). However, no significant difference in the path from consumer innovativeness to the attitude toward cryptocurrency was found (|diff| =0.148, *p*= .317), rejecting H5(b). Finally, the attitude toward cryptocurrency had a stronger positive effect on the intention to adopt cryptocurrency in the low LOHAS group than in the high LOHAS group ((|diff| =0.315, *p* < .05), indicating H5(c) reversely supported. Table 4 shows the MGA results.

Table 4: Multi-Group Analysis Results

Relationship	Low LOHAS (N=117) β	High LOHAS (N=106) β	Low versus High |diff|	*p*-value
CI → INT	0.17	0.49	0.32	0.03
CI → ATT	0.19	0.34	0.15	0.32
ATT→ INT	0.68	0.37	0.32	0.01

5. Discussion and Conclusion

The present study found psychological factors that influence consumer intention to adopt cryptocurrency. Our results showed that consumer innovativeness positively explained the intention to adopt cryptocurrency. This indicates that consumers with openness to new trials and a desire for early adoption of new items tend to have greater intention to use cryptocurrency. This is supported by other studies indicating consumer innovativeness as a significant driving factor for new technology acceptance (e.g., [11], [12]). Second, we found that consumer innovativeness is positively associated with attitude toward cryptocurrency. This shows that highly innovative consumers tend to positively evaluate cryptocurrency and favor trying them. It aligns with past literature suggesting that consumer innovativeness is a significant driver of a positive attitude toward the use of technology-based services [54]. Third, we revealed that attitude has a positive relationship with intention to cryptocurrency, and this demonstrates that the more one has a positive attitude toward cryptocurrency, the more one is likely to intend to use it. This confirmed the predictive ability of attitude on intention in the cryptocurrency context. Fourth, the mediating effect of attitude in the relationship between consumer innovativeness and cryptocurrency intention was proven. This implies that a part of the total effect of consumer innovativeness on intention to cryptocurrency is due to mediation by attitude [55].

Finally, we found the moderating role of the LOHAS lifestyle in the relationship between consumer innovativeness and intention to adopt cryptocurrency. Specifically, a positive moderating effect was revealed, meaning that the impact of consumer innovativeness on the cryptocurrency intention is enhanced when the consumer lives the LOHAS lifestyle. This adds empirical evidence to other research that indicated that LOHAS consumers are innovative early adopters who tend to learn, try, and adopt new technology more than any other segment [39], [56]. However, there was no significant moderating effect on the impact of consumer innovativeness on attitude. This indicates that the impact of consumer innovativeness on attitude toward cryptocurrency does not differ depending on the level of LOHAS. Finally, while the moderating effect of LOHAS in the relationship between attitude and cryptocurrency intention was found, the effect of attitude on intention was greater in the low LOHAS group than in the high LOHAS group. The weaker influence of attitude on the intention to use cryptocurrency in the high level of LOHAS consumers may suggest that there might be some potential factors that mitigate the effect of the positive attitude of consumers high in LOHAS on the intention to use cryptocurrency. This encourages future research to examine any demographic, psychographic, or contextual factors that influence the impact of the LOHAS lifestyle on the intention to cryptocurrency.

5.1 Theoretical Implications

The findings of this study provide theoretical implications. First, we developed a theoretical model to understand the determining psychological factors of consumers' cryptocurrency adoption intention. Employing consumer innovativeness as a personality trait with another antecedent of attitude, this study founds how and why consumers intend to adopt cryptocurrency. Although academics have examined the cryptocurrency behavior within the TPB, few studies considered incorporating other individual difference factors in conjunction with TPB to better understand the empirical relationship between psychological motives and cryptocurrency behavior. This bears theoretical implications for future scholarly attempts to examine the ongoing adoption of cryptocurrency among consumers. Second, while the majority of the literature has focused on the determinants of cryptocurrency adoption from a technological perspective (e.g., innovative products, the complexity of products, ease of use), this study helps to better understand the underlying mechanism of consumers' cryptocurrency adoption. Third, our findings provide significant empirical evidence of the LOHAS consumers' innovative predisposition to technology. While previous researchers conceptually inferred that the LOHAS consumers adopt technology-based products earlier than other segments, this study empirically tested it and supported the previous discussion.

5.2 Managerial Implications

This study has several managerial implications. First, we found that the effect of consumer innovativeness on intention to adopt cryptocurrency is partially mediated

by attitude. This provides businesses with insights into the need of appealing to the benefits of cryptocurrency (e.g., transaction transparency, fast transaction, security, and safety) as an alternative transaction/payment option to increase consumers' favorable attitude [57]. Second, our findings on the likelihood of innovative consumers adopting cryptocurrency indicate that a new demographic profile may have access the cryptocurrency. Given that cryptocurrency users often represent newer and more cutting-edge customers of the company, businesses would need to put themselves in a position for cryptocurrency transactions with significant stakeholders [58]. Third, as consumers high in the LOHAS lifestyle are more likely to intend to adopt cryptocurrency, businesses in health, well-being, or sustainability sectors may consider incorporating cryptocurrency into their business models as a payment, transaction, reward, or compensation method. Utilizing cryptocurrencies in day-to-day businesses may encourage the development of new and creative trade of healthy and sustainable goods and services, extending the market reach of the businesses [59].

5.3 Limitations and Future Directions

The study has several limitations and suggestions for future research. First, this study only includes attitude as a mediating factor between consumer innovativeness and cryptocurrency intention. Even though the inclusion of attitude increases the empirical relationship between personality traits and behavior in a specific context [28], future research may consider incorporating other psychological and/or external factors such as perceived behavioral control and/or subjective norms that predict behavioral intention in a more systematic manner. Second, the present study found that the impact of attitude on intention is less in the high LOHAS group than in the low LOHAS group. The result encourages future research to identify potential influential factors that generate the attitude-intention gap, particularly in high LOHAS consumers. For example, LOHAS consumers' environmental consciousness might discourage them from actually using cryptocurrency for its negative environmental impact regardless of their positive evaluation of other aspects of cryptocurrency (e.g.,[60], [61]). Finally, while this study measures consumer innovativeness based on a one-dimensional construct, future studies could use various subdimensions of consumer innovativeness as predictors of cryptocurrency intention to provide a more in-depth understanding of the role of consumer innovativeness on the intention to adopt cryptocurrency.

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Analyzing the Measurement Accuracy of 3D Reconstruction for Small Objects using Different Software; A Case Study

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ABSTRACT:3D reconstructions are widely used, the main challenge of them is the accuracy especially for small and detailed objects. Various software exists for 3D reconstruction, free and paid ones with various performances. In this paper the performance of 3D object reconstruction will be evaluated in terms of size accuracy. The aim of the paper is analyzing the size accuracy of the reconstructed 3D models based on photogrammetry for small objects. Meshroom is used for 3D photogrammetry reconstruction and various software are used for measurement. MeshLab, Meshmixer and Blender and 3D Slicerare used for measurements, all are free software's. Experimental results show a high accuracy for objects sizes measured using Meshmixer.

KEYWORDS: Photogrammetry, 3D reconstruction, Meshroom, MeshLab, Meshmixer, Blender, 3D Slicer, size accuracy, small objects

1. Introduction

Undoubtedly that the uses of 3D computer vision are growing at an extraordinary rate in different fields of industry, among which we can mention 3D printing, archeology and medical, etc. As the fields for 3D application possibilities are constantly increasing, so are the various solutions for providing these technologies. The aim of the paper consists in the study of software that provides 3D reconstruction from images taken with usual camera, a mobile phone camera or a professional one. The software used for 3D reconstruction based on photogrammetry is Meshroom [1]. It is a free, open-source 3D Reconstruction Software based on the AliceVision framework [2]. AliceVision is a Photogrammetric Computer Vision Framework which provides 3D reconstruction and camera tracking algorithms [2]. Meshroom is designed as a nodal engine [3]. This is a very special feature of Meshroom because the parameters can be changed very easily. It allows to add other nodes besides those provided by default, and the parameters for the added nodes can be modified easily. Meshroom is developed in Python while the AliceVision framework is developed in C ++ [3]. It is as a very good place for 3D reconstruction based on photogrammetry, for analysis and for measurements [1]- [6], widely used by researchers.

The dimensions of the object reconstructed in Meshroom are determined to compare the measured values of the target object with the real ones. For measurementsfour different software's will be used, MeshLab, Meshmixer, Blender and 3D Slicer. Based on the comparison, the optimal solution will be concluded.

Section two describes the methodology used in the paper, section three describes the experimental part and its analysis of results, concluding with the conclusions of the paper.

2. Methodology

2.1. Photogrammetry

Photogrammetry is a technique that enables the creation of 3D models from photos taken from real objects in different positions, possibly keeping the object static [3][7]. It works by extracting 2-D data and superimposing them. Since objects are of different sizes, photogrammetry is used in various fields and applications such as topographic maps or points clouds [8]. The process of obtaining 3D models would be much more complex if we did not use modern software today.

For this article the software we will use are Meshroom, MeshLab, Meshmixer,Blender and 3D Slicer.

2.2. Meshroom Software

The photo inputs are placed below the left-top part, the right-top part serves to display the output of the photo processing (more specifically it serves to display the final output, the created 3D object, but in this position can also be displayed the result of special nodes when executed). The bottom part is undoubtedly the most important part, more specifically in the left-bottom part is given the graph editor which shows the nodes that participate in the workflow execution. As we mentioned, the nodal environment makes Meshroom software very special because each node is performed individually. While the bottom-right section shows the characteristics for each particular node, more specifically the outputs, statistics and status are displayed as shown in figure 1. The photos were taken by through usual cameras. The individual tasks are represented by nodes combined into directed acyclic dependency graphs that are named pipelines [9].
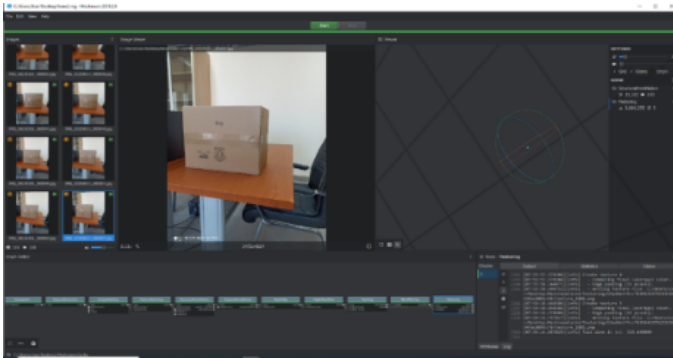

Figure 1: Interface of Meshroom

In this paper the default nodes will be used, camera initialization, feature extraction, image matching, feature matching, structure from motion, depth map, depth map filter, meshing, mesh filtering and texturing.

CameraInit loads image metadata, sensor information and generates viewpoints.sfmcameraInit.sfm. FeatureExtraction extracts features from the images as well as descriptors for those features [10].ImageMatching is a processing step which figures out which images make sense to match each other. FeatureMatching finds the correspondences between the images using feature descriptors. StructureFromMotion will reconstruct 3D points cloud from the input images. DepthMap retrieves the depth value of each pixel for all cameras that have been resolved by SFM. Certain depth maps will claim to see areas that are occluded by other depth maps. The DepthMapFilter step isolates these areas and forces depth consistency. Meshing generates mesh from sfm point cloud or depthmap. MeshFiltering filter out unwanted elements of the mesh. Texturing projects the texture change quality and size/file type of texture [10][11].

2.3. Meshlab Software

Meshlab is an open source systems for 3D image processing and preparing models for 3D printing. It works based on point clouds or in meshes. A set of tools are provided from Meshlab software as rendering, meshes, texturing, measurement of distances, cleaning, healing etc. [12].

2.4. Meshmixer software

Meshmixer is a 3D software offered by Autodesk, it is free and available in Windows and MAC OS. Meshmixer is relatively easy to use and is therefore recommended for people who have no experience in the field of 3D modeling. Meshmixer software does not offer the possibility of creating a model from scratch, but instead requires that the model must be imported once into Meshmixer and then you can make changes here.

Meshmixer is based on triangular meshes that consist of three elements: vertices, edges and faces (or triangles). The vertices correspond to points in 3D space, the edges connect two vertices together and the faces correspond to the association of three vertices [13].

2.5. Blender software

Blender is a free and open-source 3D computer software. It is used for a wide variety of applications such as the creation of animated films, 3D printing models, virtual reality, video games, etc.

2.6 3D Slicer

3D Slicer is a free, open source and multi platform software package widely used for medical, biomedical, and related imaging research [14] .

3D Slicer is a software application for visualization and analysis of medical image computing data sets. All commonly used data sets are supported, such as images, segmentations, surfaces, annotations, transformations, etc., in 2D, 3D, and 4D [15]. Analysis includes segmentation, registration, and various quantifications.

3. 3D reconstruction of small objects

Small objects are difficult to be reconstructed, they must be well distinguished from the background, especially if they have details on them and a small number of photos is required. Measuring the sizes from the reconstructed objects helps us in the assessment of cloned ones using a 3D printer. Small objects with complex shape are difficult to be reproduced and the accuracy of the sizes obtained from the 3D reconstruction plays an important role.

3D reconstruction of objects is realized in Meshroom. Its reconstruction is very sensitive from the input images, usually a considerable overlap between images is suggested to have a better reconstruction. The reconstructed object is obtained as a scaled version of the real one. To reconstruct it with real sizes, a known size

element is needed. Rescaling the reconstructed object using the known dimension, enables the acquisition of the object in real size.

4. Experimental analysis

As mentioned above Meshroom offers a nodal environment and each node will perform specific functions. The work consists in analyzing the measurement accuracy of 3D reconstruction using three different software: MeshLab, Meshmixer and Blender. The photos are taken by Xiaomi mobile phone Readme Note 8 pro. A small, detailed object is used for 3D reconstruction. As object of thestudy an ordinary office key is used and the reconstruction is done with Meshroom software. The dimensions of the reconstructed object are determined and the measurement results will be compared with the real ones.

Initially the experiment was performed by a set of 40 photos that are randomly selected for the specified object. A white surface is used as the background. Photos are uploaded to Meshroom, the process of executing the nodes went up to the node structure from motion and did not continue. This is due to the white background, which stops the photo processing in the structure from motion node.The background is changed as shown in figure 2. Randomly, 31 photos are obtained.
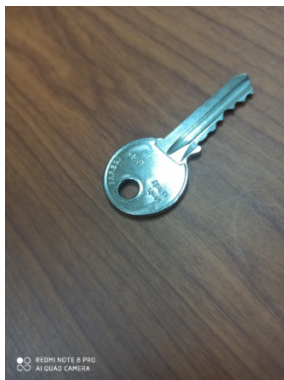

Figure 2: Target object for reconstruction

The reconstructed object using Meshroom is shown in figure 3.
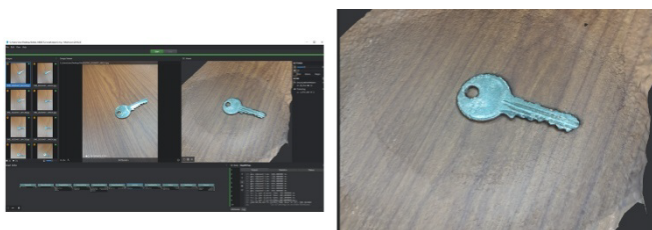

Figure 3: Reconstructed object from photos

It is noticed that the set of 31 photos as input, was all passed for further processing. The reconstructed 3D object is satisfactory recognizable, as even the most complex part of the key, which is the part of the teeth, has been completely reconstructed and is easily distinguishable.

4.1. Case I

To determine the dimensions of the reconstructed object as above specified, MeshLab will be used as the first case. The meshing that was generated by Meshroom will be imported in MeshLab and the result is shown in figure 4.

Figure 4: Object in Meshlab for measurements

As can be seen from the photo, the part of the teeth is notquite recognizable in terms of quality, but the shape of the key is satisfactory recognizable, while in the final object obtained in Meshroom (figure 3), the teeth are satisfactory recognizable. With final result that MeshLabgives, the dimensions of the object in focus are determined. Substituting the new values at x , y and z plane, the distances to be measured will be of the same nature as those of the real object.

Figure 5: Measuring the key length

Figure 6: Measuring the diagonal

The length of the measured key using MeshLab results in 5.4668 cm while the real length of the same distance is 5.5 cm, so the measurement error is 0.0332 cm as shown in figure 5.

The distance of the two key points as in the picture above measured using MeshLab results in 2.2455 cm while the real length of the same distance is 2.3 cm, the measurement error is 0.0545 cm as shown in figure 6.
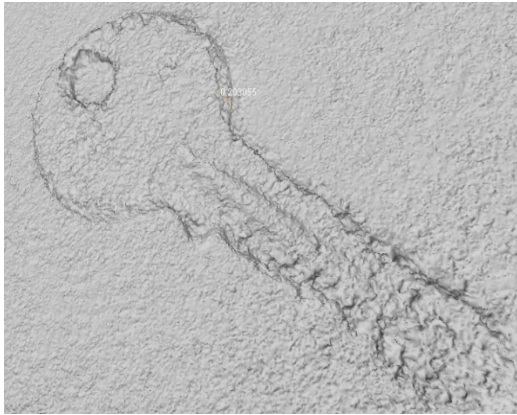

Figure 7: Measuring the key thickness

The height of the key measured by MeshLab results in 0.203 cm while the real length of the same distance is 0.19 cm, the measurement error is 0.013 cm as illustrated in figure 7.
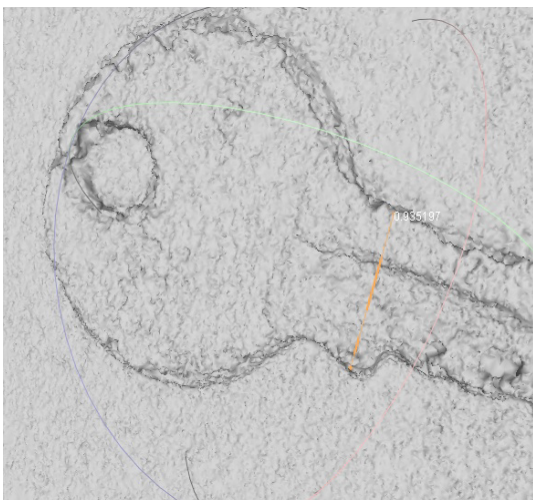

Figure 8: Measuring two ordinary points of the object

The distance of the two key points as illustrated in the figure 8 measured using MeshLab results in 0.935 cm while the real length of the same distance is 1 cm, the measurement error is 0.065 cm as shown in figure 8.

4.2. Case II

To determine the dimensions of the reconstructed object in Meshroom, the Meshmixer software will be used as the second case. Initially, the meshing that was generated by Meshroom will be imported in Meshmixer, and the result is shown in figure 9.
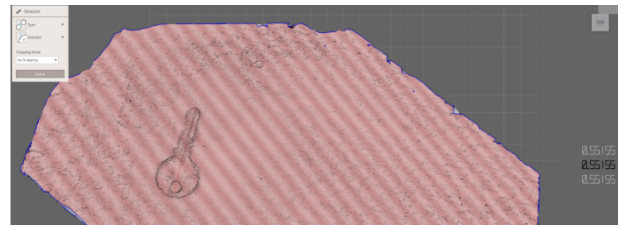

Figure 9: Measuring the key length

As can be seen from the photo, the part of the teeth is not satisfactory recognizable in terms of quality, but the shape of the key is sufficiently recognizable. The dimensions of the object in focus will be measured. Substituting the new values at x, y and z, now the distances to be measured will be of the same nature as those of the real object.

The total length of the key measured by Meshmixer results in 5.515 cm while the real length of the same distance is 5.5 cm, the measurement error is 0.015 cm as shown in figure 9.

Figure 10: Measuring the diagonal

The distance of the two key points as in the picture above measured by Meshmixer results in 2.2 cm while the real length of the same distance is 2.3 cm, the measurement error is 0.01 cm as shown in figure 10.

Figure 11: Measuring the key thickness

The height of the key measured by Meshmixer results in 0.18 cm while the real length of the same distance is 0.19 cm, the measurement error is 0.01 cm as illustrated in figure 11.
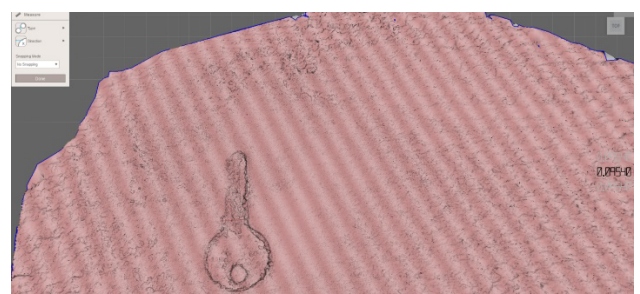

Figure 12: Measuring two ordinary points of the object.

The distance of the two key points as in the picture above measured by Meshmixer results in 0.954 cm while the real length of the same distance is 1 cm, the measurement error is 0.046 cm as shown in figure 12.

4.3. Case III

To determine the dimensions of the reconstructed object in Meshroom, Blender software is used as the third case. Initially the meshing that was generated by Meshroom will be imported in Blender and the result is as shown in figure 13.
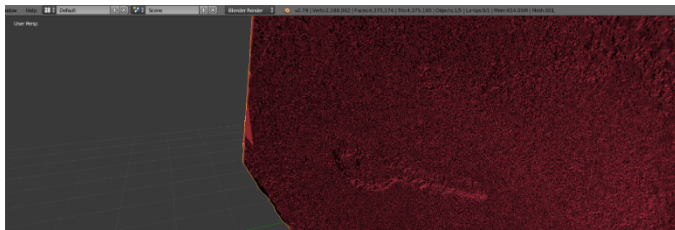

Figure 13: Object in Blender for measurements

As can be seen from the figure 13, the object in focus is not recognizable at all in terms of quality. Therefore, it is not useful to measure the distance for this reconstructed object, because the focus of this paper is to create the 3D reconstructed object as clear as possible in terms of quality. And for that reconstructed object we can try to find the dimensions. Since this is what Blender software allows us, the distances for the target object cannot be determined, concluding that Blender's performance for these types of small objects is not at a good level.

4.4. Case IV

To determine the dimensions of the reconstructed object in Meshroom,3D Slicer software is used as the fourth case. Initially the meshing that was generated by Meshroom will be imported in 3D Slicer and the result is as shown in figure 14.
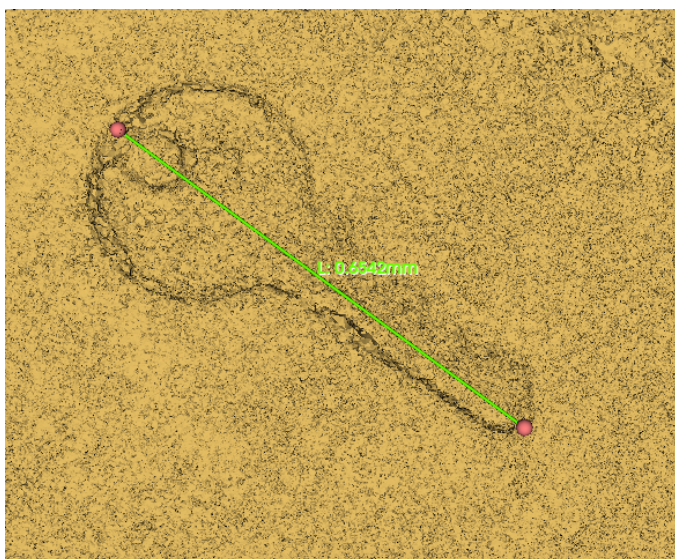

Figure 14: Measuring the key length

As can be seen from the photo, the part of the teeth is not sufficiently recognizable in terms of quality. The dimensions of the object in focus will be measured.

The total length of the key measured by 3D Slicer results in 6.54 cm while the real length of the same distance is 5.5 cm, the measurement error is 1.04 cm as shown in figure 14.
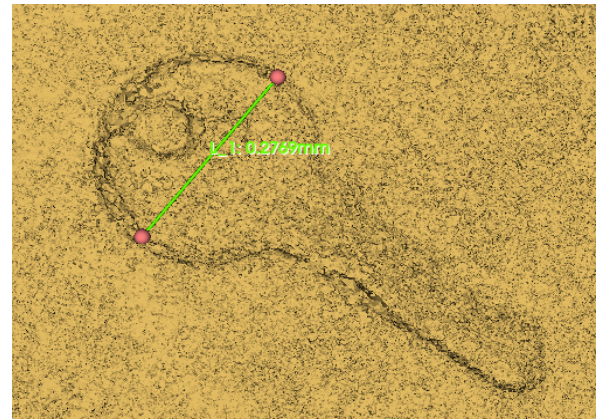
Figure 15: Measuring the diagonal

The distance of the two key points as in the picture above, measured by 3D Slicer results in 2.7 cm while the real length of the same distance is 2.3 cm, the measurement error is 0.4 cm as shown in figure 15.

5. Performance comparison

The results of the measurements and quality for three software used are shown in table 1.

Table 1: Performance comparison

Software	Visuality	Length error (cm)	Diagonal error (cm)	Thickness error (cm)	Two ordinary point error (cm)
Meshlab	Satisfactory recognizable	0.0332	0.0545	0.013	0.065
MeshMixer	Sufficiently recognizable	0.015	0.01	0.01	0.046
Blender	Insufficiently recognizable	N/A	N/A	N/A	N/A
3D Slicer	Sufficiently recognizable	1.04	0.4	N/A	N/A

As we can see from the above results, Blender is eliminated, while MeshLab gives the best result, followed by Meshmixer and 3D Slicer, in terms of quality. But in our analysis we also include the dimensions of the reconstructed objects. As we showed above, taking in consideration the dimensions of the reconstructed objects, the best results are given by Meshmixer, followed by MeshLab. So from the analysis we can easily eliminate Blender and 3D Slicer. And as the best result we choose Mexhmixer, because both it and MeshLab are recognizable in terms of quality,but since we are in small objects, the determination of the dimensions also plays a decisive role. And as can be seen from the measurements in the table 1, MeshMixer gives the best results.

6. Conclusions

Changing the background from white in a suitable one brought the possibility of processing all Meshroom nodes to generate the reconstructed 3D object. In this paper the focus was on small objects possibly with complex shapes.

The reconstructed object with a set of 31 photos resulted in a satisfactory recognizable, complemented by content and clear contours. Having a known size element of the object, the reconstructed object is scaled. The dimensions of the small object are measured in four different software: MeshLab, Meshmixer, 3D Slicer and Blender and a comparison is done between them. Experimental results show that dimensions of the object are obtained with high accuracy in a range of errors between 0.013 cm to 0.065 cm in MeshLab and in a range of errors between 0.01 cm and 0.046 cm in MeshMixer.

In conclusion, the best results are those provided using Meshmixer software with an average error of 0.3 mm and sufficiently recognizable in terms of quality.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

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A Survey into Challenges and the Need for Heating Element Technology in Root Canal Procedures

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ABSTRACT: Root Canal Treatment (RCT) is one of the most common endodontic clinical procedures performed in the field of dentistry amounting to almost 25 million performed every year. It is thus essential for endodontists to ensure best practices. However, through a recent survey, it has been observed endodontists resort to supplemental methods and protocols during procedures due to the scarcity of precision devices in the market. This not only compromises sound practices but also elevates the risk of operational failures & additional infections at the cost of the patient. Despite this deviation, the survey further highlights that touch and heat devices offer better stability, precision, and safety. This paper sets out to explore the ongoing challenges faced by endodontists in this field particularly in the methods to cut Gutta-percha and seal the canal and establish the need for heating element technology in such procedures.

KEYWORDS: Gutta-Percha, Root Canal Treatment (RCT), Sybron-Endo, Touch and heat

1. Introductsion

Root Canal Treatment (RCT) is used to extirpate a damaged or infected tooth pulp and clean and seal the interior of the tooth with gutta-percha to avoid further spread of infection [1]. The pulp of the tooth is a soft chamber within the tooth comprising nerves and blood vessels. The nerve endings are located near the root of the tooth and canals travel from the root tip to the tooth chamber. The tooth pulp gets affected and infected due to deep decay, multiple repeated dental procedures, large fillings, a crack in the tooth, or trauma to the face.

Infections due to deep cavities are one of the most common reasons leading to infections. When the pulp gets infected, a chemical breakdown occurs, and it becomes a site harvesting exponential bacterial growth [2]. A prolonged effect of increasing bacterial growth and the decomposing pulp will lead to pus formation. In the dental field, this process can be referred to as the formation of an abscessed tooth. The pus pocket or abscess is primarily categorized into a periapical abscess which forms at the tip of the tooth's root and a periodontal abscess that affects the bone next to your tooth. This abscess formation can lead to the following issues-

- Spread of infection and swelling to other tooth, gum area and in severe but rare cases also affecting cheeks.
- Loss of bone around the tip of the root
- Generation of a hole cutting straight through the tooth and gums leading to a draining problem and increasing direct exposure to vital internal systems .

Thus, treating it as early as possible to avoid any further implications is of paramount importance. Endodontists provide RCT to the patients. However, due to ongoing challenges in the treatment procedures especially in the gutta percha cutting - sealing phase has probably made endodontists resort to unsafe practices which can be hazardous to the patient. We thus seek to assess and address the issues faced specifically in the gutta percha cutting sealing phase by doing a survey on ongoing challenges and get valuable inputs from endodontists. Based on the survey results we also seek to establish a need or a proposed methodology to overcome the difficulties faced in this profession [3].

2. Literature Review

2.1. Root Canal Treatment Procedure

In the RCT procedure the endodontist first proceeds to take an X-ray to assess the structure of root canals and

determine any other affected area including infections on the adjacent bone. While performing the endodontist uses anesthesia to numb the surrounding area and places a sheet of rubber – rubber dam to avoid flow of saliva. A hole is then drilled through the tooth or through the existing cavity exposing the pulp and the infection as shown in Figure 1. All residual pulp is then removed. Continuous water treatment ensures remaining debris is removed. The endodontist then cleans the canal track using files, scraping the walls clean.

In presence of other internal infections, the endodontist provides treatment and may decide to seal the canal later. In such a case the tooth is filled with a temporary filling. In other cases, the endodontist seals the canals directly. This is done using a sealer and cones of a rubber compound gutta percha. These cones are tapered and are available in varied sizes to fit into the canal structure. Different techniques are used for filling in the Gutta percha cones and are outlined below.

Gutta-percha is a natural latex and is obtained from Palaquium Gutta and several other trees of East Asia. Based on their manufacturing process gutta-percha can be classified in two distinct forms (α and β) which can be interchangeable. During the manufacturing process, if the cooling is done rapidly, it results into the 'β' form which is the most commercially available form, whereas if it is cooled slowly, less than 0.5°C per hour, α form is produced. Typical properties of α include sticky, lower viscosity, fluid while β form is solid, compactible, has higher viscosity and can be elongated. Following are the various techniques of sealing and filling the canal with Gutta percha [4].
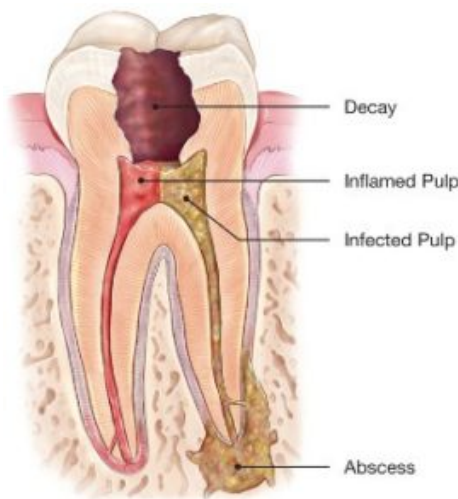

Figure 1: RCT Procedure [5]

2.1.1. Lateral compaction of gutta-percha

In this particular technique, gutta percha cones are compacted laterally one over the other against the canal walls as shown in Figure 2. This technique has two subtypes – cold compaction and warm compaction. The cold lateral compaction comprises of arranging the gutta percha cones and filling the canal. Though it offers advantages such as

simplicity, no additional cost, or specific instruments its disadvantages include risking formation of air gaps or voids and requires high precision. Additionally, gutta-percha placement is key in this technique to avoid inadequate filling.

The warm compaction method seeks to overcome these limitations by applying heat to the gutta percha. This is done usually using a heat carrier electrical device supplying constant heat to the tip. The soft gutta percha will provide better flow and result in a dense root filling. The cones are placed in a similar fashion to the cold compaction technique and then are pressed with a heated tip to provide better seal. Additionally, it will result in better flow through the root canal complexities. These specific instruments have a sharp tip for lateral compaction, and a blunt plugger tip for limited vertical compaction of the softened gutta-percha.
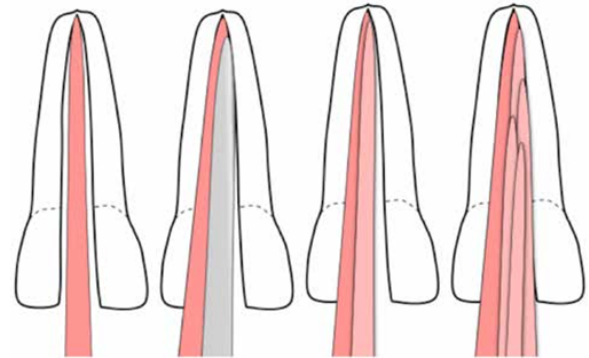

Figure 2: Lateral Compaction [6]

2.1.2 Vertical compaction of gutta-percha

This technique is similar to the heated lateral compaction only differing in the compaction axis. The soft gutta percha is pressed down vertically and the cones are added over the other to complete the filling and eventually obturate. As shown through Figure 3 gutta-percha cone is placed in the canal. The heated device tip then melts the gutta-percha providing fluid flow though the canal and with slight pressure the lower part of the canal is sealed. More cones are now added above the sealed portion and the process is repeated until the canal is filled [7].

In both methods heat and touch devices are used, the tip dimensions however differ in both techniques, but usually different tips can be attached to a single device based on application. Heated gutta-percha flow in both lateral and vertical compaction techniques provide the best sealing for canals. Vertical compaction method delivers the best results with very high accuracy however is used in rare cases as it is time consuming and takes time to be mastered [8]. It is not as widely used as lateral heated compaction as the latter is more feasible and easier to use. This method is useful in situations such as internal resorption, C- shaped canals, or canals with fin and webs.
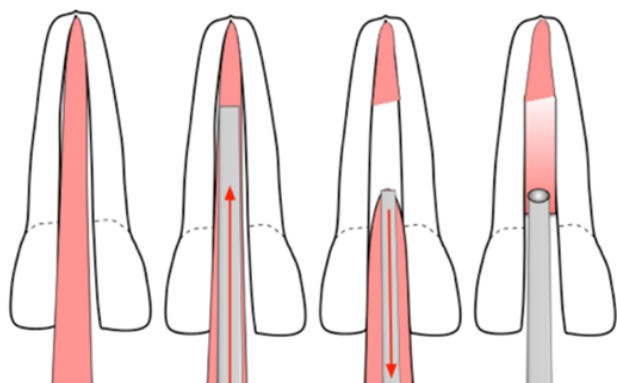
Figure 3: Vertical Compaction [6]

2.2. Gutta-Percha heated carriers

This method uses alpha-phase gutta-percha which gets attached around a rigid plastic heated carrier. It is placed directly in the canal and excess material is removed. The carrier and gutta percha once placed remain in the canal as shown in Figure 4. The carrier functions as a heated support structure. The softened gutta-percha then flows through the canal sealing it off completely. This technique however requires cleaning and canal shaping precision. The carrier's structure and canal structure must match perfectly for a good fit. An irregular fit can cause problems such as formation of gaps between walls and the sealant [7].
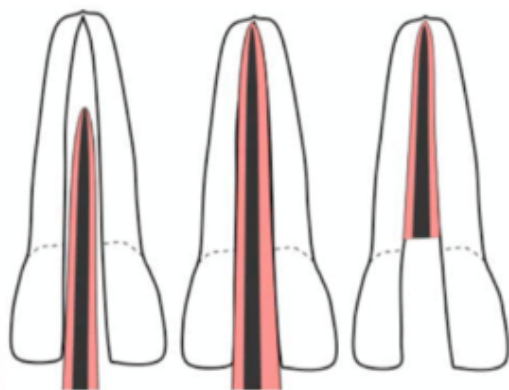

Figure 4: Heated-Carriers [9]

2.2.1. Single gutta-percha

This technique utilizes the concept of custom fitting based on canal geometry. However, each individual may have unique structures, and the feasibility of this method is hence limited. A single gutta percha matching the structure of canal is used and in a single movement it is fitted in the canal. This method is usually not recommended [10].

2.2.2. Thematic compaction of gutta-percha

This method uses the principle of friction. A device having blades is used to compact and soften the gutta percha using frictional heat. It then drives the gutta percha deep into the canal. This technique however requires very high

precision and practice to master. Additionally, low control has made this method unfit for practice as compared to other techniques.

2.2.3. Injectable gutta-percha

This is a developing technique focusing on directly injecting soft gutta – percha or sealant using obturation device. This technique however is not as effective. Each complex and deep canal structure would require a unique custom obturation tip to ensure complete flow, reach and sealing. Moreover, air gaps can be created if the device obturation tip falls short of the depth of the canal. These limitations make the technique less viable [11].

The heated lateral compaction technique is the most widely used technique for obturation although in some cases vertical heated compaction may also be used. The basic principle behind achieving this is to provide a constant heat supply through a narrow tip. The final step of the RCT procedure may include providing restoration of tooth. This is done to provide protection and avoid breaking [4]. It can be done through crown fitting, crown, and post. Thus, heat and touch devices form an integral part of the RCT. We hence seek to explore the available devices and challenges faced by endodontists in usage of such devices to ensure maximum accuracy [12].

2.3. Current methods & devices to cut and seal Gutta Percha

We now investigate the current available devices or methods used, and their features. As clearly indicated in Table 1 Sybron Endo outweighs all other devices/ techniques in use currently

Table 1: Methods and devices used

Method/ Device	Principle	Positive Aspects	Negative Aspects
Direct Flame Usage	Heat slender rod directly on flame	Cheap	No accuracy, fire hazard, no constant heat supply.
Woodpecker Touch and Heat[1]	Electric Heating	Handheld, suited for vertical compaction, 4temperature settings	Tip quality mediocre, Costly.
Sybron Endo Touch and Heat 5004[2]	Electric Heating	High precision, most trusted, Variable heating, Ease of use &	Costly, No longer manufactured

			convenience, Variable tip size facilitating both compaction techniques,
Napple GP Cutter	Electric Heating	Handheld offering high mobility and operability, cheap,	Tips are not usually made of high quality or geometry to suit compaction. Life expectancy is low.
Gutta Cut (VDW GmbH, Endodontic Synergy) Germany.	Electric Heating	Induction charging unit + 4 tips, rechargeable, Ni-Cd battery	Low quality tips, low life expectancy 80 cuts per battery charge.

3. Survey Results

We proceed to start with a questionnaire survey relating to challenges faced in the Gutta – Percha cutting and sealing phase of the RCT, advantages of touch and heat devices & the methods used currently. We try to infer the reasons behind the deviations from safe practices using this survey. Thus, our primary focus would be to find endodontists not using touch and heat devices despite having practiced or learnt about it earlier. With consultation of endodontists, we estimate minimum required sample size (n) to be 43 assuming a 95% confidence level, margin error (δ) 0.15 and proportion outcome (φ) 0.5.

$$n = \left(\frac{1.96}{\delta}\right)^2 \emptyset(1 - \emptyset)$$

The survey was conducted through more than fifty endodontists majorly across Pune Municipality region, and across India. Detailed analysis of the results can be found in the next section.
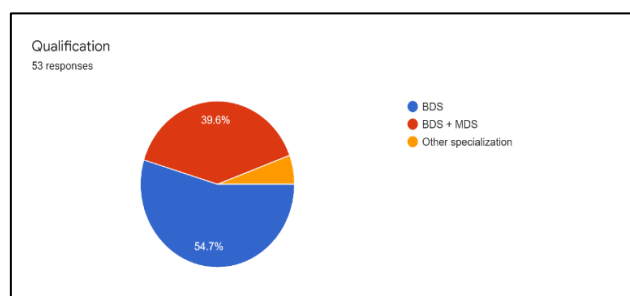

Figure 5: Results – Population Background (i)

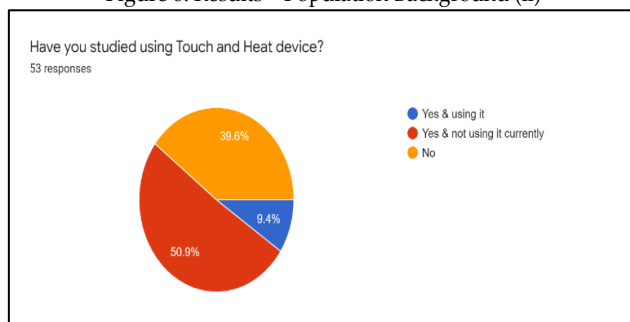Figure 6: Results – Population Background (ii)

Figure 7: Results – Population Background (iii)
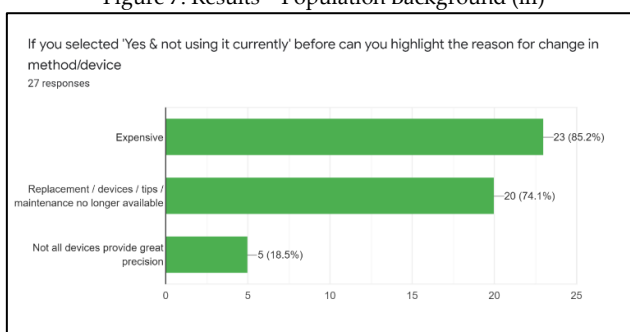
Figure 8: Results – Challenges in using Touch and heat devices.
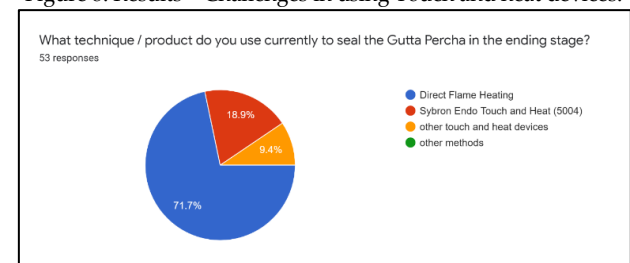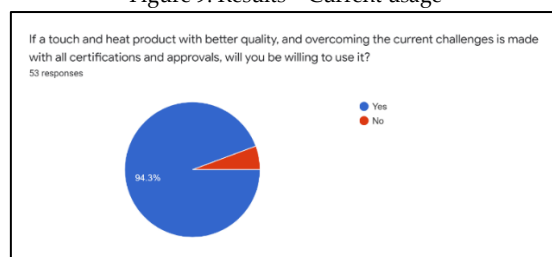

Figure 9: Results – Current usage

Figure 10: Results – Need/Demand

Table 2: Responses to new techniques and used techniques by practitioners

Any new techniques coming up for the same purpose / have you used different techniques apart from your current technique?
Heated root filling material (Injectable Gutta-Percha)
Cold Flowable Gutta-Percha (Research Stage)

Table 3 : Responses advantages of techniques under use

How does your current technique differ from touch and heat devices? (Advantages)
I) Sybron and other Touch and Heat Devices
Easy to heat and cut the gutta percha
User friendly, highly accurate (Sybron)
Less time consuming, convenient
Better flow and sealing of Gutta-Percha
Continuous heat flow ensures good compaction
I) Direct flame Heating
Economical, Quick
Effective, Fast, minimal maintenance
Requires practice to attain precision.

Table 4: Responses Disadvantages of techniques under use

How does your current technique differ from touch and heat devices? (Disadvantages)
I) Sybron and other Touch and Heat Devices
Costly, high maintenance
Irreplaceable parts if device malfunctions
Sybron has stopped manufacturing and other devices don't offer similar accuracy.
II) Direct Flame Heating
Lifting of Gutta-Percha Points during procedure
Poor seal and flow, less accurate
Complex structures cannot be easily accessed.
Cannot reach Tertiary roots
Not patient friendly, can cause burns and other injuries

4. Analysis

It is observed from Figure 5 that out of the survey population 39.6% have not studied using touch and heat devices and resort to direct flame heating and it can also be seen 41.5% have more than 15 years of practical experience. It was found that the theoretical aspects of such touch and heat methods were covered in the dentistry curriculum much recently, thus possibly explaining usage of the direct flame heating methods. However, it can also be observed through Table IV that this method has low accuracy and poses as a hazard if not practiced with precision. From Figure 10 it can be inferred that if touch and heat devices are made with lower costs, and ease of usability, this population

bracket is willing to switch to a much safer and accurate method.

On the other hand, 60.4% of the population are familiar with the usage of touch and heat devices, but figure 1.7 reveals that only 9.4% use such devices for RCT implying only 15.56% of this population bracket is willing to practice with these devices. It can be clearly observed from Table III that the advantages of touch and heat devices especially Sybron Endo 5004, clearly outweigh those of the direct flame heating in terms of safety & precision. Touch and heat devices further allow better flow of Gutta Percha through canal leading to better sealing. These devices also facilitate reaching into complex canal structures and tertiary roots. The table IV also highlights numerous disadvantages of the direct heating technique like possible burning of lips/cheeks and non- stable heat flow. Thus, it is evident from these results that touch, and heat devices are safer and highly accurate and direct heating method although cheap, can be hazardous to the patient. Yet only 15.56% of this population bracket chooses to practice said technique.

Figure 8 tries to explore the possible reasons behind endodontists deviating from this technique. 85.2% of the respondents cited cost as one of the reasons while 74.1% cited unavailability of device maintenance, parts, or replacement. Endodontists resort to usage of direct flame heating whenever the touch and heat device malfunctions. A touch, and heat device Sybron Endo, with its features listed in table I has the highest market share in this segment. Its positive features outweigh all other touch and heat devices. However, it was noted that Sybron has currently shut down its operations across India and devices and other accessories if available are imported at heavy costs.

It can be inferred from Figure 9 that Sybron Endo is the most used and trusted device during RCT procedures and thus its scarcity has impacted its practice. Unavailability of device maintenance and replacement parts makes this device unviable. Furthermore Figure 8 and Figure 9 also conveys that despite a broad market endodontist do not prefer to use other devices citing quality concerns. Other touch and heat devices as also highlighted in table I do not seem to match either the quality or the precision of the Sybron device. A combined effect of scarcity and unreliable products in the same segment has potentially caused endodontists to shift to unsafe practices.

Table II highlights 2 upcoming techniques cold flowable gutta-percha and injectable gutta-percha. The first technique is in its nascent stage while the second technique faces issues as highlighted in section 2.1.6. Thus, any significant developments to improve quality of other touch and heat devices to match Sybron endo has not been possible yet. This possibly explains why endodontists are currently resorting to direct flame heating technique which is a cheap substitute but raises operational risks. Figure 10 and Table III conclude that practitioners would prefer to use touch and heat devices

over direct flame heating technique which in turn can ensure safe practices. Thus, it is evident that there is a need to develop highly accurate touch and heat approaches in this field to assist endodontists for better accuracy and safety.

5. Conclusion

Touch and heat devices offer better stability, reliability and safety compared to direct flame heating technique. They are more accurate and can reach complex structures with ease. They also have stable heat flow ensuring proper cutting and sealing. Although costs for touch and heat devices in the market are substantial. Additionally direct flame heating technique poses dangers to the patient such as burns.

The survey results showed that unavailability of touch and heat devices in particular Sybron Endo 5004 or parts for replacement and other unreliable market players have made majority of the endodontists move to direct flame heating technique as a cheaper alternative. Others cite concerns over precision and functionality of other heat and touch devices as a reason of shift to direct flame heating technique.

Having high quality touch and heat devices for the purpose of compaction and Gutta Percha cutting is a necessity to ensure safe, accurate practices and endodontists would prefer to use such devices provided they get necessary certifications from the medical board.

Conflict of Interest

The authors declare no conflict of interest.

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Design Consideration for IGBT-Based PWM Inverter-Fed Induction Motors

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ABSTRACT: Pulse width modulated (PWM) inverter has applications in many areas as it offers control of voltage, frequency, and harmonic in one power stage. In the practical design of three-phase inverter circuits, a proper understanding of the operations and peculiarities of the specific model to be built is necessary. Most often, perhaps due to different models and configurations; these details are often omitted or assumed to be obvious. An IGBT-based PWM inverter for a 0.5hp induction motor was designed and implemented. Though the implementation posed a challenge to realize, the experience obtained during the process informed the design consideration presented in this paper. The power supply requirements, gate drive requirements, driver protection and dv/dt protections are necessary considerations for successful implementation. This paper presents detailed specific requirements when designing a PWM inverter with IGBT as a driver for induction motor application. The focus is on the theoretical analysis and important design considerations during the practical implementation of an inverter. Different stages involved are analyzed and discussed from the input stage to the output load section. The model used involved single-phase ac input which is rectified to dc. At the output of the rectifier is a large filter capacitor to maintain a constant dc link voltage. The insulated gate bipolar transistor was used as a switching device to drive the 0.5hp induction motor. The analysis simplified inverter design, especially for beginners.

KEYWORDS: Pulse-Width-Modulated (PWM), Rectifier, Insulated Gate Bipolar Transistor (IGBT).

1. Introduction

The growing need for variable voltage and frequency has increased the popularity of inverter circuits in the industry. Some of the control strategies which made this possible are voltage control or six-step, pulse width modulation current control techniques [1]. Minimization of harmonics and ripple in torques can be achieved by the PWM control technique and properly selected filter[2,3,4]. The PWM technique can be categorized into various types according to different patterns of reference signal [5]. Thus, the inverters formed are named after each technique. For controlling PWM, it involves turning ON and OFF the switch continuously during a half-cycle and the output voltage is controlled by varying the width of the pulses [6]. The driving force behind the usage of AC drives system is the cost, maintenance, size reliability and efficiency advantages of the ac induction motor.

Though the use of conventional methods for generating PWM causes variable frequencies at the output of an inverter [7]-[9]; they are still popular because of easy implementation and cost-effectiveness. PWM can be an open loop or a closed loop configuration depending on how the generated voltage reference is used. It is directly given as a reference in the open loop while it is fed to the controller in the closed loop [10]. PWM inverter has its area of application in industrial motor drives and uninterrupted power supply (UPS) systems as it has excellent modes of speed control of the induction motor [11]. The high efficiency and superiority of induction motors over DC motors are factors responsible for the high rising of their usage in industries [12], [13]. With renewable energy on the increase in recent times, an inverter which serves as a link to the grid will continue to find application in this area as well [14]. The switching element is an insulated gate bipolar transistor (IGBT). Its choice of usage is because of the combination of the advantages of bipolar junction transistor (BJT) with that of metal oxide semiconductor field effect transistor (MOSFET). Each of the IGBTs is switched between the dc

poles to give the ac output [15]. Previous works revealed the simulation method [7] and practical implementation of the PWM stages [8]. This paper now focuses on the other details involved during the practical implementation of an inverter circuit. The full results and performance test analysis of the inverter are not reported in this paper.

2. Material And Methods

To design and implement successfully a three-phase inverter circuit, a proper understanding of the operations and peculiarities of the specific model to be built is necessary. This paper presents detailed specific requirements when designing a PWM inverter with IGBT as a driver for induction motor application. The stages involved are segmented into five sections. They are the input/rectifier, capacitance dc link, IGBT driver, PWM stage and AC induction motor. The theoretical analysis and design considerations involved in practical implementations were highlighted. Figure 1 shows the block diagram for the whole system. Each of the sub-sections is discussed next.
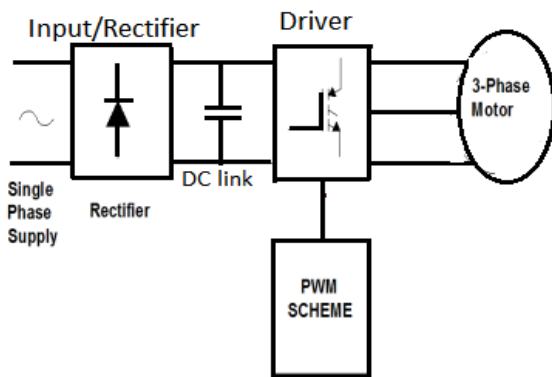

Figure 1: Block diagram of a Three-Phase PWM Inverter under consideration

2.1. Input /Rectifier Design Stage

DC sources for inverters can be from renewable energy sources such as solar, wind etc depending on other factors. It can be from the grid also for ac-dc-ac operation as illustrated in this work. The input stage for the inverter considered is AC power supply from the grid. AC supply has been chosen as the source of supply because of its wide acceptability and most used form of power supply, especially in the industry. The input dc to the inverter is a rectified single phase ac supply. The rectification process is usually done to reduce the harmonic content in the supply current and thus produces a high input power factor [4]. Single-phase supply input is used in this work because the load is relatively small (0.5hp/0.37kw induction motor). Though the 3-phase is commonly used for industrial applications, the same approach for the single-phase used in this paper can also be adopted with

necessary modifications. A resistor is placed in the input to prevent a large inrush current during startup [16].

For the operation of an inverter, different stages may require different power supplies due to various voltage demands in the circuit. They are high-voltage and low-voltage sections. In this model, the high voltage source is for the inverter to drive the load. This is achieved by directly converting the 220 a.c source to its equivalent d.c source using a full bridge rectifier. A capacitor is then used to filter the ripple. Note that no transformer is involved in this case.

The low voltage d.c source stage is further made up of two sections:

(i) ±15V supply: this section supplies both positive and negative voltage to the PWM control/driver circuit.
(ii) +5V supply: this supplies to the logic circuit.

A 15V step-down transformer is used to supply both circuits with voltage regulators LM7815, LM7915 and LM 7805 to obtain +15V, -15V and +5V respectively from the rectifier output as shown in Figure 2.

The second stepdown transformer of 12V rating in Figure 2 is used to supply the phase shift circuit (PSC) as discussed in [7]. Details are therefore not presented here for brevity.

3. Design analysis

The design of a rectifier involves the determination of the ratings of diodes which are normally specified in terms of average currents, rms current, peak current and Peak Inverse Voltage (PIV).

For the D.C link (being a highly inductive load), the power is given by equation 1 as:

$$P = V I \cos \theta \quad (1)$$

The phase current is then given by equation 2 as:

$$I = \frac{P}{V COS\theta} \quad (2)$$

Substituting for the values of P, V and power factor $\cos \theta$ as 370W, 220V and 0.75 respectively.

$$= \frac{370}{220 \times 0.75} = 2.24A$$

The average load current is chosen as 2.5A assuming the ripple is negligible.

For the peak inverse voltage PIV:

$$PIV = \sqrt{2} \times 220 = 311V.$$

Based on this design, a 400V diode is chosen.

The line-to-neutral voltage of 220V/50Hz is the average current of the diode given by:
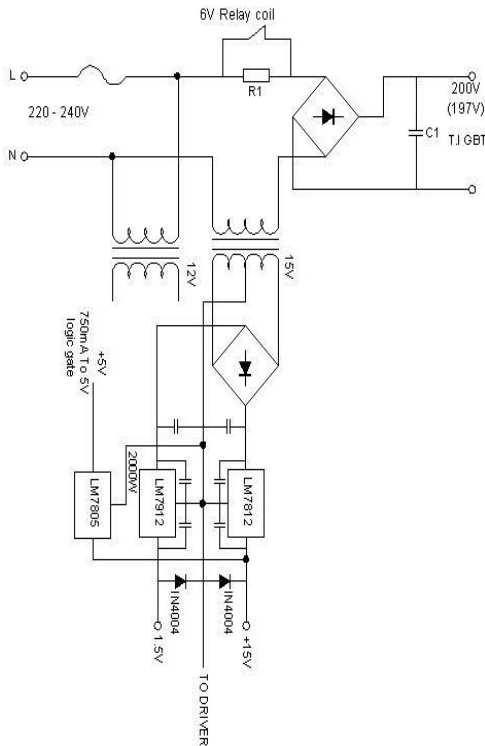
$$I_d = 2.5/0.5 \text{ A} = 5\text{A}$$

Figure 2: Schematic diagram of power supply.

3.1. Capacitance Link (DC Link) Stage

For voltage–source inverter, a large filter capacitor is placed across the inverter input terminals to maintain a constant stiff dc link voltage and to reduce low-order harmonics [17]. Because of the large value of C, the time constant RC is also large compared with the periodic time (0.02s for 50Hz) of the applied voltage [16]. There is an exponential decay of the voltage across the load as against a sinusoidal fall given by equation 3.

$$V = V_{max} e^{(-t/RC)} \qquad (3)$$

To be effective, the reactance, x_c of the capacitor should be relatively minimal compared with the resistance R. To keep ripple less than $1V_{P-p}$, the required capacitor is given by equation 4 as:

$$C = \frac{I * T}{2 * V_{p-p}} = \frac{I * T}{2 * f * V_{p-p}} \qquad (4)$$

where I is current, T is period and f is the frequency.

For a current of 2.5A obtained above and 50Hz supply frequency, the value of the capacitor required is:

$$C = 2.5/(2 \times 50 \times 0.1)$$

$$C = 2,500 \mu f$$

A 2,500µf capacitor is chosen.

3.2. Insulated Gate Bipolar Transistor (IGBT) Driver Stage

When designing a gate drive circuit for IGBT, it requires that the gate charge is used rather than the components value based on the gate capacitance listed in the datasheet. This is because the RC values based on them normally lead to inadequate values because of the Miller effect. A gate charge is defined as the charge that must be supplied to the gate to swing the gate by a given charge known [18]. The required gate drive current is derived by dividing the gate charge by the required switching time. The circuit impedance can equally be determined. The gate charge data also allows the determination of average gate drive power. The lower the charge, the lower the gate drive current needed to achieve a given switching time [19]. Equation 5 gives the average gate drive power as:

$$P_G = Q_G. V_G. F \qquad (5)$$

where P_G is gate power, Q_G is the total charge and f is frequency.

3.3. Opto-coupler

To isolate the control circuit from the power circuit, an opto-coupler is necessary. An optical isolator is to provide protection from high-voltage transient, surge voltages and low-level electrical noise that could damage the device or from erroneous output [18]. They allow the interfacing of a circuit with different voltage levels and different ground. An opto-coupler consists of a light source such as LED and a photo detector [19]. Figure 3 shows the circuit diagram of the opto-coupler used.
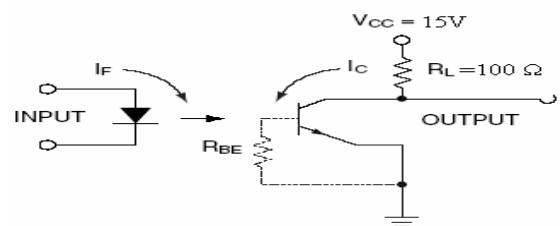
Figure 3. The Opto-coupler

3.4. Driver Output Stage

The output section of the inverter is driven by the driver circuit according to the switching frequency. A specially designed driver IC by International Rectifier (IR2110) [20] is employed in this model. IR2110 was used to drive the high upper and lower side of the bridge. It provides a simple low-cost high-performance solution to the gate drive requirements [21]. It is a high-voltage, high-speed IGBT driver with independent high and low side

referenced output channels. It has a floating channel which can be used to drive the IGBT in the high-side configuration up to 500V maximum. Figure 6 shows the final stage of the IGBT PWM inverter circuit with the IR2110 Driver

Figure 4: Final stage of the IGBT PWM Inverter circuit with the IR2110 driver

4. Gate Drive Circuit Design

The gate charge Q_g for the IGBT used (IRG4PH50U) is 160 nC from the datasheet. The total capacitance gate (C_g) is obtained from

$$Q_T = C_g V_g \qquad (6)$$

With the gate voltage of 15V,

$$C_g = Q_T/V_g$$
$$= 160 \times 10^{-9}/15$$
$$= 10.67 \text{nF}$$

The power required to charge the gate is calculated as:

$$P_g = \frac{1}{2} C_g V_g^2 f \qquad (7)$$

where f is the switching frequency.
With a switching frequency of 1500Hz, from equation 7 we have:

$$`P_g = 0.5 \times 10.67 \times 10^{-9} \times 15^2 \times 1500$$
$$= 1.8 \text{mW}.$$

The power dissipated (P_D) in the gate drive circuitry can be obtained from equation 8 as:

$$P_D = C.V^2.f \qquad (8)$$

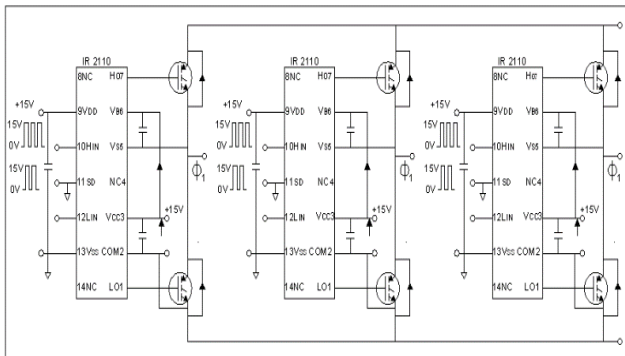where C is the total capacitance gate obtained above; V is the gate voltage and f is the switching frequency. Substituting for the values, we have:

$$P_D = 10.67 \times 10^{-9} \times 15^2 \times 1500 = 3.6 \text{mW}.$$

5. Driver Protection

To provide a path for reverse currents for the totem output transistor, low forward voltage drop Schottky diodes are generally needed to protect the outputs. The diodes must be placed very close to the outputs path to the bypass capacitor of the driver. It should be noted that the diodes protect the driver only and thus they are not clamping the gate-to-source voltage against excessive

driving. The driver circuit handles the current spikes and power losses making the operating condition for the PWM controller more favourable. The driver circuits therefore should be placed next to the power IGBT they are driving.

5.1. dv/dt Protection

IGBT must be protected against dv/dt triggered-on during the power-up and in normal operation. During power-up, this is done by a resistor placed between the gate and source terminals of the device. High dv/dt in power supply has been reported to generate high stress on motor windings and thus require additional motor insulation [21]. It also increases the electromagnetic interference (EMI) caused by semiconductor devices.

5.2. PWM Stage

In the three-phase inverter, each half-bridge is fed with the same triangular carrier wave with the reference wave displaced by 120^0 for a balance system. For a balanced three-phase operation, it is essential to operate with a carrier ratio that is multiple of three. The ratio of the reference amplitude wave to the carrier wave is termed the Modulation Index.

It determines the notch width in the modulated pole voltage waveform and therefore controls the fundamental output voltage of the inverter [22]. The practical implementation of the PWM techniques has been presented by [8].

The sinusoidal pulse width modulation (SPWM) method popularly used in the industry was adopted with a unique phase shifting technique6,11. The detailed simulation and implementation have been reported [7,8].

5.3. AC Induction Motor (ACIM)

ACIMs are the popular choice of motor control in industries. Some of the advantages of ACIM include simple and rugged design, low maintenance and direct connection to AC power. When power is being supplied to the induction motor at the specified time, it runs at its rated speed. Three-phase induction machine is mostly used in industries as they can deliver more power than the single-phase. Squirrel cage induction motor is the most popular among induction motors. The rotor motor type requires an external resistor and slip rings connection. The squirrel cage motor has a simple and rugged construction. The rotor consists of a cylindrical terminated core with axially placed parallel slots for carrying the windings. Each slot can either be of copper, aluminum or alloy bar and are usually short-circuited at both ends by means of end ring [1]. It forms a case-like cage hence its name.

The stator winding is directly connected to the power source to a create rotating magnetic field rotating at synchronous speed Ns given by equation 9 as:

$$N_s = \frac{120f}{P}$$ (9)

where f is the supply frequency in Hertz and P is the number of poles on the stator.

Synchronous speed is the speed at which the stator flux rotates. Rotor flux rotates slower than this synchronous speed by the slip speed. The slip speed is the difference between the synchronous speed and the base speed. That is:

Slip speed = Synch speed (Ns) – base speed (Nb)   (10)

The per cent slip is therefore given as:

% slip = Ns - Nb   x 100%   (11)

The complete circuit model for induction motor is shown in figure 5.

where: X_s is per phase leakage reactance of stator winding; R_s is the resistance of the stator; Xm is magnetizing reactance; Rm is resistance for excitation; Im is magnetizing current; Rr is rotor resistance and Xr is leakage reactance.
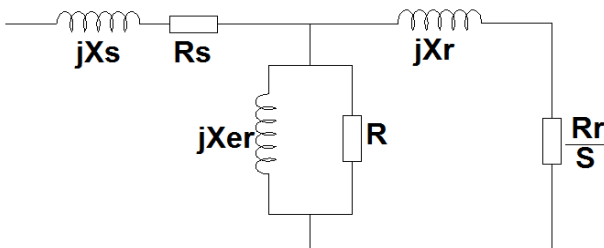
Figure 5: Per phase equivalent circuit of an induction motor

The inverter circuit with a three-phase bridge connected to the motor's stator winding is shown in Figure 6. The modus-operandi of a three-phase AC induction motor (ACIM) requires a rotating magnetic field which is normally supplied through the stator windings. An inverter-fed induction motor is a popular form of adjustable-speed ac drive, because of its wide availability and low cost [1].

6. Result

The complete model of the three-phase PWM inverter consists of all the various stages previously highlighted coupled together. Figure 7 shows the complete circuit model under consideration. Figures 8 and 9 show the IGBTs circuitry and DC link capacitor respectively during the practical implementation. The triangular wave and clocking signal used for realizing PWM waveforms

obtained during the implementation are shown in Figures 10a and b [8].
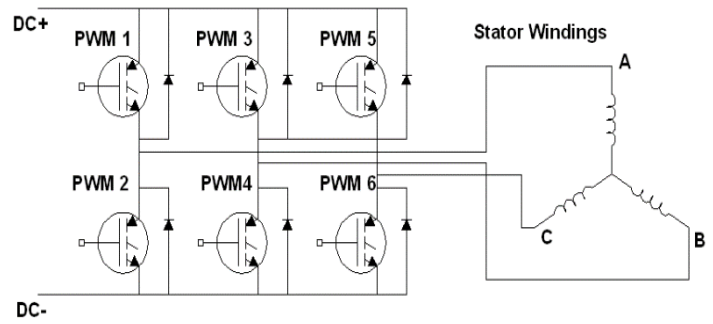
Figure 6: Power Inverter Circuit
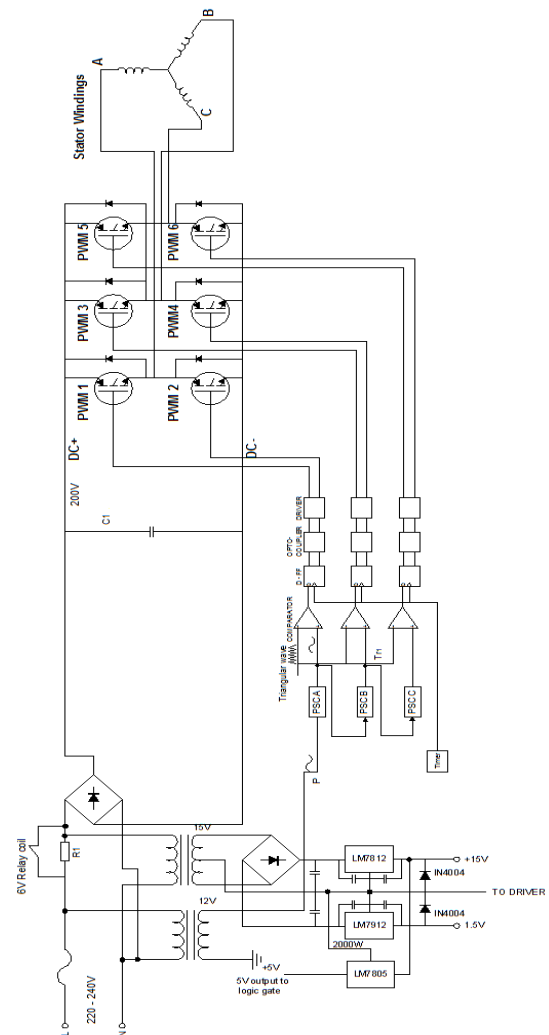
Figure 7: Complete Circuit Diagram for Three-phase PWM Inverter System
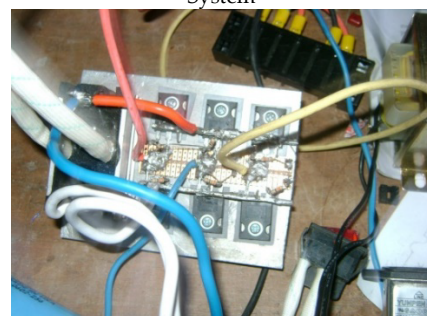
Figure 8: Power Inverter showing the six IGBTs
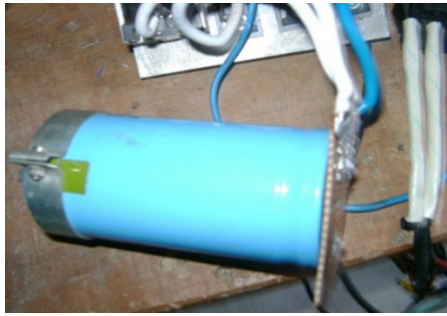
Figure 9: The 2,500μF Capacitance Filter used
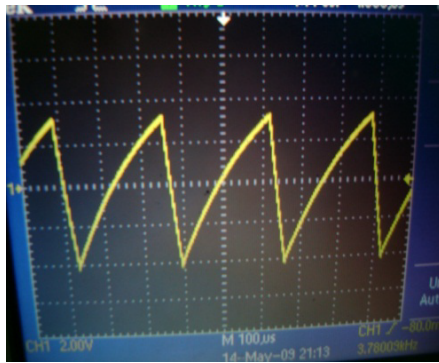
a)

b)

Figure 10: a) Triangular (Carrier) Wave from Oscillator. b) Clocking signal[11]

7. Discussion

The complete circuit and practical implementation shown in Figures 7-10 confirmed the design analysis to be correct. Though the implementation posed a challenge to realize, the experience obtained during the process informed the design consideration presented in this paper. The gate drive requirements, driver protection and dv/dt protections are necessary for successful implementation [23]. The input power supply stage to three different sections must be properly isolated from each other. Though the simulation results obtained showed the proof of concept for the design was correct [24]. However, the final choice of components differed slightly from the simulation result. The ideal elements are usually employed in a simulation circuit. The most challenging parts of the implementation are the PWM and driver circuits. The problems of grounding, interference etc. associated with analogue circuits are properly

handled to get the appropriate signals [25]. The screenshot of the triangular carrier wave from the oscillator circuit and the clocking signal as reported in [8] following the simulation of [7].

8. Conclusion

PWM inverter remains popular among power-electronic circuits in practical applications and will continue to attract research interest. PWM control techniques are one of the ways to improve the harmonic-free environment in high-power converters. This paper has presented the design consideration for a three-phase PWM inverter in induction motor application. Though a single-phase was used in this work, the principle of operation remains like that of three-phase. The design concept earlier simulated showed that the proof of concept used was correct. The easy implementation and control features have been explored to illustrate the design consideration emphasized in this paper. The interconnected circuitry such as power supply stages, DC link, PWM circuit, driver stage and load section. Though the design used analogue techniques, in this smart era of microprocessor-controlled devices; digital implementation will be a better option for improved performance. This paper does not present the full results of the performance test. A details harmonic analysis of the harmonic waveforms is necessary to determine the quality of the waveform.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

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Stakeholder's Perception of Critical Success Factors for Design-Bid-Build Highway Projects in Nigeria

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ABSTRACT: Project success factors are germane in achieving project objectives by stakeholders. The research investigates the stakeholder's perception of project success factors for highway project in Nigeria. Therefore, the specific objectives is to identify and assess factor influencing the success of highway project in Nigeria. To achieve the main objective of this paper, two hundred (200) questionnaires were administered on major stakeholders in the highway sector; comprising highway engineers both in consultancy firms and client organisations, and quantity surveyors using random sampling technique. Ninety-four (94) questionnaires were found useful for the analysis, yielding a response rate of 47%. Statistical Package for Social Sciences (IBM SPSS Version 22) was used in analysing the data. The results indicated that clear project goals (4.68), experienced design team (4.59), proper project planning (4.51), availability and adequacy of resources (4.50) and on time decision making (4.48) in that order are the most CSFs in highway projects in Nigeria. However, a Kruskal-Wallis test conducted showed that there is no statistically significant difference in the ranking scores among the three (3) stakeholders at 5% significance level, except for four out of the twenty two factors assessed. The group means vary slightly from the individual means obtained from different stakeholders but there is no significant difference in the means. The slight variation is due to the difference in opinions of the stakeholders as each group has priority for different project objectives. The paper concluded that these CSFs need to be given serious attention if the issues of cost and time overrun, project abandonment and litigation have to be a thing of the past in the Nigerian construction industry.

KEYWORDS: Critical success factors, highways, construction projects

1. Introduction

Any nation's ability to flourish economically and socially depends on its construction sector. Numerous variables affect how well a project performs and can result in a successful construction project. According to [1], there are specific factors, referred to as "critical success factors" that are more crucial than others in construction projects. [2], referenced in [3] defined critical success factors (CSFs) as "the few primary areas of activity in which favourable results are obviously obligatory for a particular management to attain his or her goals". According to [3], CSFs directly affect cost, time, quality, and safety, which are the primary metrics used to determine a project's success.

CSFs are useful when making key decisions. Hence, ranking the CSFs of projects is significant. The majority of highway construction projects in Nigeria are plagued by a variety of issues, including insecurity, cost overruns, quality issues, and delays [4]-[6]. Many road contractors, whether working for small local businesses or government agencies, have underperformed or failed to complete their assignments, especially when it comes to road maintenance [7]-[9]. The government's attention was drawn to the criticism of their work, which compelled it to create performance contracts and even establish the authority to monitor the contractors' "performance."

However, the poor performance of the road contracts is due to poor management of funds and poor delivery of services to the road user. In addition, performance measurement systems are not effective or efficient to overcome this problem. This measure put in place by government has not really brought about the desired result in achieving project objectives. There is need to look at the critical success factors which have significant impact on project objectives. Therefore, the aim of this

research is to identify and rank CSFs of highway construction projects in the Nigerian construction industry with a view to improving DBB highway projects in Nigeria.

2. Literature Review

2.1. Critical Success Factors

There has been a lot of literature on the subject of CSFs [10]. Many authors have utilized it in a general way for all projects [11-14], but others have used it specifically for each project. According to [12], the CSFs were derived in various investigations using general conceptual criteria. Other authors, according to [11], employed particular execution techniques. They added that the majority of the earlier research had mostly only identified the CSFs for project success in general. Few studies, according to [13] and [14], have identified the CSFs of public construction projects. However, there have been significant building projects that have included CSFs. Furthermore, CSFs in projects carried out by public-private partnerships were identified by [15]. For different people, success has varying degrees of significance and power.

Furthermore, CSFs might alter over time and among various nations. Additionally, it is significantly impacted by the nature, size, and participants on the project. As a result, it is quite difficult to establish a definite and consistent notion for these components. For all scholars who are concerned with the growth of the construction sector, the study of these issues is still crucial despite this. The DBB projects that served as the basis for the CSFs in this study were not given substantial consideration in Nigeria as previous researches were generic and not project specific [16, 17]. The literature and the opinions of specialists were used to create the CSFs for this investigation. Lists of CSFs and authors are included in Table 1.

2.2. Design and Build Highway Projects.

The most frequently used and least risky is the Design-bid-build (DBB) procurement method among all the conventional approaches, provided the model is well implemented [18, 19]. DBB is the traditional method of project delivery which has been widely used for procuring highway projects in Nigeria [19]. It is a linear process where one task follows completion of another with no overlap. It commences with the client (Government) selecting an engineering firm to carryout the design and prepare documents for the highway. Contractors are then invited to bid for the construction of the project as designed and the lowest responsible, responsive bidder is awarded the job. DBB has its own shortcomings. The main criticism is conflict and adversarial relationship, delayed completion, cost overrun, poor buildability, multiple point responsibility, lack of innovation and that owners bear large proportion of risks in design and construction [19]. Design and Build procurement approach gives way to a single contractor, solely, the responsibility to design and construct the project. Though, DBB procurement method is capable of reducing fragmentation at project level between contractual partners. Therefore, it subjects both clients and contractors to greater risks due to low level of design at the time of contract award [20, 21].

2.3. Highway Project Development in Nigeria

Despite enormous potential in human and material resources in Nigeria, the country is yet to harness the resources available to its full potential. This has affected the growth of the economy. The country is still suffering from inadequate provision of highways. The road density in Nigeria is currently 0.206km/km2 compared to 0.212km/km^2 in 2014, a large proportion of which are unpaved [22].

Highway infrastructural provision in developing countries are found to be insubstantial, majority of which are not accessible for all weather [19]. Majority are unpaved and those paved are not properly maintained. This has been a major concern for government and all stakeholders in the sector. Tables 2 summarizes the highway infrastructure conditions in selected African countries for the period between 2010 and 2021.

The road density as seen in Table 2 indicated that African countries have the lowest total road density of 0.26km/km^2 and an average paved density of 0.06km/km2. This is low compared to other parts of the globe, especially Europe with total road density 1.320km/km^2 and an average paved density of 1.120km/km^2 [19]. The neglect of the rail system and excessive pressure on the existing highways causes a lot of damages which make them deplorable. In [19], the author stated that one-third of existing highways in Sub-Sahara Africa is lost to overloaded and aging vehicles and trucks. The bad state of highways in Nigeria is responsible for high cost of transportation, and the multiplier effect of which is reflected on the cost of goods and services [23]. Hence, these CSFs must be evaluated to ensure that our highways are put in proper shape.

3. Research Methods

This study essentially employed the use of descriptive survey techniques and quantitative research design using the questionnaire method. This paper involved the use of pilot studies to ensure clarity and relevance of the drafted questionnaire.

Table 1: Critical success Factors and Authors

S/N	CSFs	Authors
1.	Adequate security for workers	Developed
2.	Experience design team	[12]
3.	Correct estimate of project cost	[12]
4.	Effective scheduling and time control system and frequency of project schedule updates	[12]
5.	Experienced Project Management	[12]
6.	Commitment of all parties to the project	[12]
7.	Perception of the role and responsibility	[12]
8.	Proper project planning	[13]
9.	Preparing clear quantity take-off	[13]
10.	Connect the contract price with the price index	[13]
11.	Managerial and organizational skills	[13]
12.	Utilization of Advanced technology	[14]
13.	Creating accountabilities, experiences, roles and responsibilities for the organization	[14]
14.	Allow sufficient time for feasibility studies, design, drawings and tender preparation	[15]
15.	Effective site management	[24]
16.	Implementing an effective quality control and assurance systems	[24]
17.	Experienced subcontractors	[24]
18.	Effective communication and coordination	[25]
19.	Preparing adequate and comprehensive specifications	[25]
20.	Competitive procurement process	[25]
21.	Competitive procurement process	[25]
22.	Implementation of safety management system	[29]
23.	Regular equipment maintenance	[31]
24.	Allocating appropriate fund	[32]
25.	Effective quality control system	[12], [24]
26.	Clearing right of way obstructions before mobilization of contracting company to the site	[9], [27]
27.	On time decision making	[10], [27]
28.	Proper dispute resolution clauses incorporated in the contract	[14], [25]
29.	Implementing an effective safety program	[13], [34]
30.	Clear project goals	[24], [25]
31.	Frequent meetings among various stakeholder to evaluate the overall performance and reports update	[14], [35]
32.	Availability of resources (human, financial, raw materials and facilities)	[24], [26]
33.	Developing positive friendly relationships with the project stakeholders	[14], [36]
34.	Fast troubleshooting capabilities	[25], [26]
35.	Equipment availability	[24], [28]

Table 2: Highway Infrastructure conditions in Major African Countries, 2010-2021

Countries	Total Road Length	Length of Paved Road	% of Paved Road	Land Surface Area ('000)	Total Road Density	Paved Road Density
Morocco	58,395km	41,116km	71.00	444	0.132	0.093
Kenya	160,886km	11, 187km	07.00	569	0.283	0.019
Nigeria	200,200km	75, 000km	38.90	923	0.206	0.077

Ghana	109,515km	13, 787km	12.59	228	0.480	0.059
Egypt	65,050km	48, 000km	73.80	996	0.065	0.048
Cameroon	121, 501km	7, 252km	05.97	473	0.257	0.015
South Africa	750, 000km	158, 952km	21.00	1, 213	0.618	0.131
Algeria	127,000km	98, 213km	77.30	2, 737	0.048	0.038
Average					0.261	0.06

Source: Central Intelligence Agency (2014), Knoema (2021)

The drafted questionnaire was shown to six professionals in the research field to review. Three questionnaire were administered on professionals who are university lecturers not below the rank of senior lecturers and others are practising professionals. Amendments were made on the drafted questionnaire based on suggestions of the reviewers. This was concluded before the final questionnaires were administered to the respondents. This study population is made up of civil engineers, quantity surveyors and client organisations (government) in Lagos and Ogun State, Nigeria. The sample size was obtained using the Krejcie Morgan formulae, having obtained the population from the Federation of Construction Industry (FOCI) and respective professional institutes of the professionals. A sample size of 210 was obtained. The questionnaires were generated using the responses obtained from the group of professionals in the construction industry for the purpose of data collections. The respondents to the questionnaire are the practitioners in the construction industry within Lagos and Ogun state. This method of data collection is significant as it helps in the collection of first-hand information from the direct personnel involved in the subject matter of this research. The questionnaire contains two sections: section A which contains questions that helps to identify the respondents and their relevance to the study together with their level of experience; and Section B which which consists of questions on the critical success factors of DBB highway projects in Nigeria. It contained a table of critical success factors of DBB highway projects in which the experts were requested to tick their opinions based on their experience in the industry. 35 critical success factors in all, 34 derived from literatures and one developed by the authors and verified by the experts in the pilot studies were presented in the table.

Using five point Likert scale questionnaire survey, the respondents were asked to indicate their perceived level of criticality for each of the identified CSFs by selecting any of the five evaluation scales; "Highly critical"(5), "Critical"(4), "Somewhat critical"; "Rarely critical" (2); "Not critical" (1). The questionnaires were administered to respondents by the researcher. The purpose of the research was explained to the respondents to gain their consent and assurance was given of the confidentiality of their response and protection of their identities. The data collected was subjected to statistical analysis using Statistical Packages for Social Science (SPSS IBM Version 22). The descriptive statistics of simple percentage and mean were used in presenting the analysed data.

4. Results

Table 3 shows the socio-economic characteristics of the respondents. Items 1 show respondents' type of establishment. The result of the analysis depicts that 31.9% of the respondent are client, 29.8% are consulting while 38.3% are contracting. Items 2 in the table show respondents' profession. The result of the analysis depicts that 61.7% of the respondents are civil engineer, while 38.3% are quantity surveyor. Items 3 in the table shows respondents' field of specialization. The result of the analysis depict that 46.8% of the respondents are into new work, 6.4% are maintenance work, 29.8% are civil engineering works while 17% are building/civil engineering. Items 4 in the table show respondents' academic background. The result of the analysis depicts that 30.8% of the respondents are HND, 31.9% are B.Sc., 33% are M.Sc while 4.3% are Phd holders. Items 5 in the table show respondents' work experience. The result of the analysis depict that 23.4% of the respondents are between 1-5 years of work experience, 14.9% are between 6-10 years of work experience, 54.3% are between 11-15 years of work experience while 7.4% are between 16-20years of work experience. Item 6 on the table shows the respondents' profession qualification. The result of the analysis depicts that 38.3% of the respondents are NIQS/RICS while 61.7% are NSE/COREN. This implies that majority of the respondent are NSE/COREN. The demographic information shows that the respondents

have adequate and requisite experience to have participated in the research.

4.1. Discussion of the results

This paper evaluates the critical success factors of Design-Bid-Build highway projects in Nigeria. Table 4 shows the responses of the respondents on critical success factors (CSFs) of DBB highway projects in Nigeria. The first rank on CSFs is "clear project goals" with mean score (4.88). This is followed by "experienced design team" with group mean score (4.63). The third ranked CSF is "proper project planning with group mean score (4.58). The next two factors ranked are "availability and adequacy of materials" (4.46) and "on time decision making (4.41) respectively. The least critical success factor is "allocating appropriate fund" with group mean score (3.51). The mean scores obtained for each of the stakeholder vary slightly due to individual interest to be protected by each. For example, the contractor has the highest individual mean score for "proper project planning" (4.66) as against consultant (4.64) and client (4.44). However, for on time decision making, the client has the highest mean score (4.56) while the consultants and contractors have (4.34) and (4.33) respectively. The point here is that each stakeholders have interest to protect. One novel result of this research is the establishment of the factor "Adequate security for the workers" (3.90) as one of the critical success factors in the Nigerian highway construction subsector. The huge some being demanded by kidnappers and bandits is detrimental to the success of the industry because construction as a business to contractor has a margin of profit. It is becoming a norm in the country that security operatives are attached to companies executing highway projects in Nigeria. These findings are in agreement with the studies of [10], [14], [26], [27], [35], [25], [24], [30] and [8]. In all these studies, though, the mean scores obtained by previous studies vary slightly, these same factors were considered critical. The reasons for the slight difference in the results could be attributed to the fact that while some of the previous authors worked on PPP projects, some worked on generic projects, and few on D&B projects. This result obtained for the 22 critical success factors is high on a scale of 5. The study adapted [37] scale i.e. <1.50 = Not critical, 1.50-2.49 = less critical, 2.50-3.49 = somewhat critical, 3.50-4.49 = critical and ≥4.50 = highly critical. Hence, out of the 35 factors evaluated, 22 factors were found to be critical for DBB highway projects in Nigeria. The problems with underperformance of highway projects are due to these critical success factors. The 22 critical success factors obtained in this paper are so

important if a success is to be achieved in the highway subsector of the Nigerian economy. If the highway sector is well developed, it has a significant impact on the economy. The man-hour loss due to traffic will be reduced, transport fare will be reduced and the menace of kidnapping especially in the bad spots on our highways will be reduced.

Kruskal-Wallis test was carried out to compare the medians of the samples of the three stakeholders that partipated in the survey. The result showed that there is no statistically significant difference in the perceptions of respondents on the critical success factors of DBB highway projects in Nigeria except for four factors (see Table 4). The four CSFs are; experience design team, correct estimate of the project, adequate security for workers and effective site management. The p-values for these 4 factors are less than 0.05 (see Table 4). The reasons for the difference in the results could be attributed to the fact that each of the stakeholders has different and diverse interests to protect. While the client will have special interest to ensure a workable design in terms of aesthetics is put in place, the contractor is looking at the buildability and profit to be made in the organization and the quantity surveyor is looking at the cost management to ensure that there is value for money on the projects being executed.

5. Conclusion and Recommendation

This study investigated stakeholders' perception of critical success factors for DBB highway projects in Nigeria. Clear project goals is very important as this will make the project faster as all the stakeholders know what to do at the appropriate time. Experienced design team is also highly essential as a critical success factors. This helps in the translation of clients' briefs into desired outcomes. Proper project planning as well as making materials needed in construction of highways is key to achieving success in highway construction. Based on the ranking analysis above, twenty-two factors were considered critical out of the thirty-five factors that were evaluated. The ranking by each of the stakeholders was based on the interest to be protected by each of them. The factors that are directly related with execution of project have highest mean scores from the contractors while those related with management of the highway projects have high mean scores from the clients and consultants. Adequate security for workers which was not found in the literature is very important in the Nigerian context as this could affect performance of highway projects. Also, these established CSFs will help to minimize the probability of uncompleted

Table 3: Analysis of the Socio-Economic Characteristics of the Respondents

SN	Items		Frequency	Percentage
1	Type of Establishment	Client	30	31.9
		Consulting	28	29.8
		Contracting	36	38.3
		Total	*94*	*100*
2	Profession	Civil Engineer	58	61.7
		Quantity Surveyor	36	38.3
		Total	*94*	*100*
3	Field of specialization	New work	44	46.8
		Maintenance work	6	6.4
		Civil Engineering works	28	29.8
		Building/Civil Engineering	16	17.0
		Total	*94*	*100*
4	Academy Qualification	HND	29	30.8
		B.Sc.	30	31.9
		M.Sc	31	33.0
		PhD	04	4.3
		Total	*94*	*100*
5	Working Experience	1-5	22	23.4
		6-10	14	14.9
		11-15	51	54.3
		16-20	7	7.4
		Total	*94*	*100*
6	Professional Qualification	NIQS/RICS	36	38.3
		NSE/COREN	58	61.7
		Total	*94*	*100*

Source: Field Survey, 2021

Table 4: Ranking responses on Project Critical Success Factors

SN	Ranking responds on Critical Project Success Factors	Client N=30 Mean	Consultant N=28 Mean	Contractors N=36 Mean	Total N=94 GM	Chi-Square Value	Kruskal-Wallis Asymp. Sig. p	RL
1.	Clear project goals	4.89	4.88	4.87	4.88	1.214	.714	1st
2.	Experience design team	4.54	4.59	4.76	4.63	15.496	.0042**	2nd
3.	Proper project planning	4.44	4.64	4.66	4.58	5.897	.421	3rd
4.	Availability and adequacy of materials	4.41	4.45	4.52	4.46	3.935	.623	4th
5.	On time decision making	4.56	4.34	4.33	4.41	6.762	.324	5th
6.	Utilization of Advanced technology	4.27	4.29	4.40	4.32	5.277	.489	6th
7	Correct estimate of project cost	4.12	4.25	4.29	4.22	13.382	.0025**	7th
8	Preparing adequate and comprehensive specifications	4.14	4.21	4.16	4.17	2.462	.786	8th
9	Effective communication and coordination	4.10	4.14	4.21	4.15	3.713	.613	9th
10	Equipment availability	4.04	4.03	4.05	4.04	2.532	.781	10th
11	Regular equipment maintenance	4.01	4.00	4.05	4.02	2.641	.762	11th
12	Use of environment friendly equipment	4.02	4.01	3.97	4.00	2.246	.934	12th
13	Experienced sub-contractors	3.98	3.93	3.97	3.96	6.624	.325	13th

SN	Ranking responds on Critical Project Success Factors	Client	Consultant	Contractors	Total			RL
		N	N	N	N			
		Mean	Mean	Mean	GM	Chi-Square Value	Kruskal-Wallis Asymp. Sig. p	
14	Implementation of safety management system	3.85	3.99	3.86	3.90	2.405	.907	14th
15	Adequate security for workers	3.87	3.84	3.99	3.90	12.496	.039**	14th
16	Competitive procurement process	3.88	3.89	3.81	3.86	7.681	.247	16th
17	Experienced Project Management	3.79	3.88	3.85	3.84	3.072	.649	17th
18	Commitment of all parties to the project	3.76	3.80	3.78	3.78	8.512	.109	18th
19	Effective site management	3.69	3.72	3.78	3.73	14.277	.013**	19th
20	Effective quality control system	3.63	3.72	3.60	3.65	2.892	.853	20th
21	Experienced subcontractors	3.51	3.62	3.61	3.58	4.359	.598	21st
22	Allocating appropriate fund	3.38	3.58	3.57	3.51	3.561	.623	22nd

Source: Field Survey 2021. GM=Group Mean N=Number of Frequency RL= Rank Level

highways projects. Project delays and subsequent abandonment will be drastically reduced if stakeholder management on highway is holistically given utmost attention due to diverse interest to be protected in construction.

5.1. Recommendation

Based on the findings of this study, the following recommendations are made.

- Federal government should urgently look into these critical success factors to restore highway projects for the betterment of the people living in this environment.
- Highway agencies should embrace project stakeholders because their experiences will influence the projects and consequently affect project success.
- A comprehensive stakeholder analysis will help to identify and track the expectations and needs of the individuals or groups to improve the performance and success of the project.
- There should be adequate security for personnel involved in highway projects because issues of kidnapping has become rampant as the workers are the main target of these dare devil men.

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