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Assessment of the Impact of Design Documentation Quality on Construction Project Delivery

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Abstract: Extant literature indicates that poor design documentation quality often results in construction project inefficiency. However, there is less effort by researchers to identify and empirically assess the significant impacts of design documentation quality on project delivery. Therefore, this study seeks to empirically assess how poor design documentation quality impacts construction project delivery. This study is a sequel to a study by the same authors that reviewed literature on the impacts of design documentation quality on project delivery based on a meta-synthesis approach. Therefore, the outcome of the meta-synthesis was developed into a questionnaire and distributed to project managers, architects, engineers, quantity surveyors, and site supervisors based on purposive sampling which obtained 127 responses. Data were analyzed statistically by determining the Relative Importance Index (RII) of each factor. The findings indicate project delays, project abandonment and cost overrun as significant impacts on project delivery. Also, improving collaboration between design disciplines and specialists' involvement during design are significant strategies to improve quality. The results provide pragmatic data to help enhance initiatives toward quality improvement. However, future studies should aim at developing a framework to improve design documentation quality.

Keywords: Assessment, construction project delivery, design documentation, design documentation quality.

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1. Introduction

The quality of construction design documentation plays a significant role in efficient project delivery due to its inevitable nature in construction. It is an important product of a project hence should provide adequate information to enhance the effective execution of the works (Agbaxode et al., 2021*a*; Akampurira and Windapo, 2019; Levy, 2018). Design documentation in practice includes; "drawings (architectural, engineering or structural); specifications; bill of quantities; schedule of rates; bids and bonds; conditions of contract; contracts" (Akampurira and Windapo, 2019; Sunday and Afolarin, 2013; Laryea, 2011; Mena et al., 2010) just to list a few. These documents are significant in a project delivery therefore, their intent must be adequately indicated to enhance project efficiency (Akampurira and Windapo, 2019; Levy, 2018).

While there is extensive use of design documentation in practice, researchers and practitioners have argued that the quality is often poor and bedevil with inaccurate information globally (Agbaxode et al., 2021*a*; Akampurira and Windapo, 2019, 2018; Levy, 2018) with significant impacts on project delivery (Agbaxode et al., 2021*b*). The impacts include a reduction in project quality, project delays and cost overruns (Tuhacek and Svoboda, 2019; Abdallah et al., 2018; Akampurira and Windapo, 2018). Therefore, efforts must be directed towards quality improvement to reduce the negative impacts on project delivery (Tuhacek and Svoboda, 2019). Various quality improvement strategies have been proposed by researchers and practitioners. These include; a measuring instrument for evaluating design documents' quality (Akampurira and Windapo, 2019); use of quality control units and checklists (Abdallah et al., 2018); and using Building Information Modelling (BIM) (Dosumu and Aigbavboa, 2018; Levy, 2018). However, poor quality design documentation still exists in the industry (Agbaxode et al., 2021*a*; Tuhacek and Svoboda, 2019; Levy, 2018) despite the proposal of these mitigative measures.

It is therefore indicative from the literature that poor quality design documentation exists and often results in construction project inefficiency. However, there is less effort by researchers to identify and empirically assess the significant impacts of design documentation quality on project delivery. Therefore, this study aims to empirically

assess the impact of poor quality design documentation on construction project delivery including quality improvement strategies. This was achieved based on the following Research Questions; (1) What factors are responsible for poor quality design documentation and how do these impact construction project delivery? (2) What are the existing strategies that aim to improve the quality of design documentation and how significant are they? However, this study is a sequel to a study by the same authors that reviewed literature on the impacts of design documentation quality on construction project delivery based on a meta-synthesis approach. The next section presents the literature review.

2. Literature Review

Design documentation significantly drives the entire construction process therefore, it is important to consider its quality. This is because, good quality design documentation will result in project efficiency and enhance project delivery (Akampurira and Windapo, 2019; Tilley et al., 2002). Also, decisions taken during the design documentation stage have the tendency of determining the quality of the finished project (Ajayi and Oyedele, 2018; Harputlugil et al., 2014). Therefore, substantial effort is required to improve the quality.

In defining design documentation quality, McGeorge (1988, *p. 357*) gave a conclusive definition for design quality as: "a good design will be effective (thus, serve the purpose for which it was intended) and constructible with the best possible economy and safety". While this is a more refined criterion for explaining design quality, some researchers explain design documentation quality based on the clarity and adequacy of the information contained and how comprehensive, precise, accurate and unambiguous it is (Laryea, 2011; Tilley et al., 2002). Therefore, in this study, the quality of design documentation is; how clear, adequate, comprehensive, precise, accurate, unambiguous and effective it is to fulfil the intended purpose and constructability.

In enhancing project efficiency, the quality of design documentation must be improved (Agbaxode et al., 2021*a*; Akampurira and Windapo, 2019; Ajayi and Oyedele, 2018). However, researchers and practitioners have confirmed that design documentation quality in practice is largely poor and often considered to be incomplete, inaccurate, conflicting and unambiguous (Tuhacek and Svoboda, 2019; Akampurira and Windapo, 2019; Levy, 2018; Philips-Ryder et al., 2013). Efforts to avert this worrying trend seem not to be yielding much results because the quality continues to drop and this has become a global phenomenon (Akampurira and Windapo, 2019; Malinda, 2017). Therefore, improving design documentation quality must be prioritized in the industry to enhance project efficiency (Agbaxode et al., 2021*b*; Akampurira and Windapo, 2018). The major causes of poor quality design documentation include; poor design drawings; omission in designs; mistakes; lack of coordination and disparities among design documents such as drawings, bill of quantities, and specifications; conflicting, inaccurate and unclear information in documents; poor specification; and a lot more (Zidane and Andersen, 2018; Dosumu and Aigbavboa, 2018).

The existence of poor design documentation quality in construction has a substantial negative impact on project delivery. It has the potential to cause project time overrun, upsurges in cost and may subsequently result in project failure (Shoar and Payan, 2021). It may also result in; shoddy works, claims, litigation, disputes, and creates room for rework (Agbaxode et al., 2021*b*; Philips-Ryder et al., 2013; Han et al., 2013; Laryea, 2011; Lopez et al., 2010; Love et al., 2010). This is indicative that poor design documentation quality significantly impacts project delivery (Ajayi and Oyedele, 2018). Therefore, it is undeniable that any improvement in the quality will result in an improvement in project efficiency (Abdallah et al., 2018). This will enhance performance, profitability and make clients satisfied (Ling et al., 2009).

The construction industry has received continuous criticism for wallowing in project inefficiency because of poor design documentation quality. Therefore, researchers and practitioners have all made a clarion call for efforts towards improving the quality. However, enormous efforts have been made globally toward addressing the problem over the years (Agbaxode et al., 2021*a*; Tuhacek and Svoboda, 2019; Akampurira and Windapo, 2019, 2018; Abdallah et al., 2018; Dosumu and Aigbavboa, 2018; Malinda, 2017). Nonetheless, the existence of poor quality design documentation is still prevalent in the industry (Agbaxode et al., 2021*b*; Akampurira and Windapo, 2019) despite the proposal of strategies by researchers and practitioners (Tuhacek and Svoboda, 2019; Abdallah et al., 2018; Dosumu and Aigbavboa, 2018).

Both current and previous studies argue the need for changes and appropriate initiatives in the construction industry to enhance the quality of design documentation (Agbaxode et al., 2021*a*; Akampurira and Windapo, 2019). While some researchers and practitioners propose holding design consultants responsible for issuing poor design documentation; others purport the use of Building Information Modelling (BIM); and paying consultants appropriate fees (Abdallah et al., 2018; Dosumu and Aigbavboa, 2018). Akampurira and Windapo (2019) also recommended the need for a measuring instrument to be developed for assessing the quality.

Despite the existence of these strategies, poor design documentation quality remains unbeatable in the industry (Agbaxode et al., 2021*a*; Akampurira and Windapo, 2019; Tuhacek and Svoboda, 2019). Consequentially, it has a tremendous impact on the efficiency of construction project delivery (Ajayi and Oyedele, 2018). However, there is less effort by researchers to identify and empirically assess the significant impacts of design documentation quality on project delivery. Therefore, this study aims to empirically assess the impact of poor design documentation quality and quality improvement strategies. The next section presents the methodology of this study.

3. Methodology

The general plan of how the study was carried out is presented. Since the study aimed to empirically assess the impact of poor design documentation quality on construction project delivery including quality improvement strategies, a positivist approach that employed quantitative research principles was used. This resulted in the use of a structured questionnaire that observed and measured facts epistemologically (Saunders et al., 2016). The questionnaire sought to elicit factual data to address the aim of the study and its relationship with existing literature findings (Creswell and Creswell, 2017; Saunders et al., 2016). All propositions in this study are

based on data collected because when the premises are correct, the findings shall be true (Saunders et al., 2016). In statistical analyses, a sample size of 30 or more is acceptable (Saunders et al., 2016). Therefore a sample size of 261 involving construction sector professionals selected through purposive sampling is used in this study. This involves a deliberate selection of research participants based on their role and qualities (Etikan, 2016) which resulted in the selection of project managers, architects, engineers, quantity surveyors, and site supervisors for this study. However, 127 participants responded giving a response rate of 49%.

3.1 Synthesizing Data for Questionnaire Design

This study is a sequel to a study by the same authors that reviewed literature and further identified and classified variables that impact the quality of design documentation on project delivery including quality improvement strategies based on a meta-synthesis approach. The meta-synthesis approach employed six major steps (Chenail et al., 2018; Erwin et al., 2011; Sandelowski and Barroso, 2007) to identify and categorize the factors which are;

1st Step: Research question formulation; the study question was "What are the impacts of design documentation quality on construction project delivery including quality improvement strategies in literature"?

2nd Step: Carrying out a systematic search of literature consistent with the research question. This was done using relevant keywords in reliable scientific databases.

3rd Step: Screening and selecting articles to answer the research question based on an inclusion and exclusion criteria (Yahyapour et al., 2015). This allowed the inclusion of research articles from 1992 to 2020 and subsequently reliability of the data.

4th Step: Analysis and synthetizations of the findings; codes were assigned to each raw finding and codes with similar content were integrated into groups (Pattern coding) with the help of QSR Nvivo 12 Pro software.

5th Step: Ensuring quality control; achieved using the Critical Appraisal Skills Program (CASP) to ensure the credibility of the articles (Yahyapour et al., 2015).

6th Step: Presentation of the findings; this served as the basis for designing the questionnaire for this study. The synthesis identified 36 variables on the impact of design documentation quality and further classified into 4 groups as presented in Fig. 1. Another set of 56 factors was identified on quality improvement strategies classified into 2 groups as presented in Fig. 2.

3.2 Questionnaire Design

Questionnaires were used to collect data for this study to assess the level of importance of each variable in the study. This enabled an efficient way to collect data where every professional responded to the same questions (Saunders et al., 2016). A five-point Likert scale was used where respondents were asked to score each factor on a scale of 1 to 5 with highly important rated as 5 and not important rated as 1, indicating the least score.

The questionnaire is composed of 4 sections. Section 1 is on demographic information; section 2 contains variables on the impact of poor-quality design documentation; section 3 contains quality improvement strategies and section 4 makes provision for comments from respondents. The questionnaire was administered online via google form using a sample size of 261.

Questionnaire validity and reliability was achieved through a pilot study using purposefully selected construction sector professionals. According to Saunders et al. (2016), it is important to ensure the validity and reliability of the data collection instrument for a study. This allowed the questionnaire to be tested to determine its capability to address the research aim by testing the variables, detecting ambiguities and allowing for factors that were overlooked to be included. The data analysis method used is presented in the next sub-section.

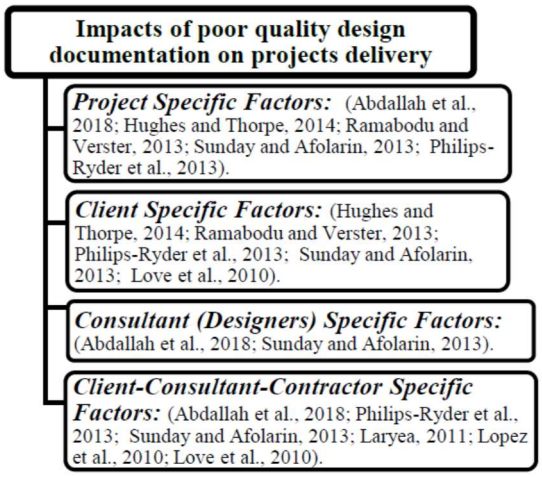

Fig. 1. Categories of macro factors on Impact

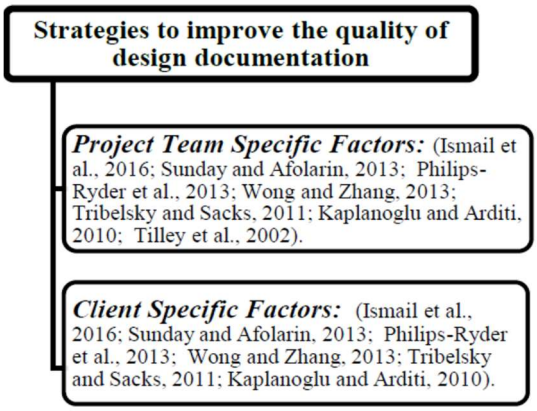

Fig. 2. Categories of macro factors on Strategies

3.3 Data Analysis Method

Relative Importance Index (RII) was used to rank the factors with the aid of IBM SPSS Statistics for Windows, Version 27.0. RII is used to determine the significance of different factors. It was used by Ribeiro and Fernandes (2010) to explore agile methods in construction. Zeng et al. (2005) also used it to identify factors in design quality. According to Holt (2014, *p. 6*), the following RII equation is mostly used in project management hence used in this study; $RII=\sum W/A \times N$.

Where W is the weighting for each factor on a scale of 1 to 5 where the least is 1 and the highest is 5; A is the highest weight (i.e., 5); and N is the sum of respondents. However, the RII is based on 5 significant levels which are; High (H) ($0.8 \leq RII \leq 1$); High-Medium (H-M) ($0.6 \leq RII \leq 0.8$); Medium (M) ($0.4 \leq RII \leq 0.6$); Medium-Low (M-L) ($0.2 \leq RII \leq 0.4$); and Low (L) ($0 \leq RII \leq 0.2$). These values range from 0 to 1 and higher values indicate higher

importance. Data analysis and discussion are presented in the next section.

4. Data Analysis and Discussions

The study population involves managing directors, project managers, architects, engineers, quantity surveyors and foremen as presented in Table 1 with their corresponding frequencies and percentages. Respondents' experiences are important in this study. From the analysis, 36% have 11 to 20 years' experience; 25% (21 to 30 years); 14% (6 to 10 years and 31 to 40 years respectively) which is indicative that they have appreciable experience in construction hence had in-depth knowledge and provided relevant responses for this study.

Respondent's level of education is significant in this study. A majority of 47% are 1st-degree holders, Masters (24%), Higher National Diploma (14%), Technicians (11%), Diploma (3%), and PhD (1%). This means respondents have attained good levels of education hence provided adequate data.

The study composed of a total of 92 factors out of which 36 factors were on the impact of poor design documentation quality and 56 factors on quality improvement strategies. These results are presented in Tables 3 and 6 respectively including respondent scores, RIIs, Ranks and Importance Levels (IL) of the factors. The mean RII and ranking of groups of factors are presented in Tables 4 and 5 respectively. This presents the groups of factors in order of significance depending on the RII of individual factors in each group.

Table 1. Demographic Data

Position in the Industry	Frequency	Percent
Foreman	25	19.7
Engineer	24	18.9
Quantity Surveyor	33	26
Architect	15	11.8
Project or Construction Manager	16	12.6
Managing Director	14	11
Total	**127**	**100**

Table 2. Impacts of poor design documentation quality on project delivery

SN	Macro Factors	Micro Factor Codes	Respondent Scores					RII	Rank	IL
			NI	I	NVI	VI	HI			
1	*Project Specific Factors*	Late completion of project or delay	3	8	0	14	102	0.92	1	H
		Project abandonment	3	8	3	22	91	0.90	3	H
		Generation of Rework	2	8	2	24	91	0.91	2	H
		Structural collapse	0	14	4	13	96	0.90	3	H
		Deterioration of buildings and Defects	1	10	5	30	81	0.88	5	H
		Constraining project efficiency	0	9	8	34	76	0.88	5	H
		Contributing to poor service quality	1	13	3	46	64	0.85	8	H
		Low productivity on construction projects	0	11	6	33	77	0.88	5	H
		Shoddy works	4	6	7	22	88	0.89	4	H
2	*Client Specific Factors*	Dissatisfaction by project owners	0	10	3	37	77	0.89	4	H
		Lack of confidence in consultants	4	6	10	63	44	0.82	10	H
		Discourages investment	1	9	11	50	56	0.84	9	H
		Project cost overrun	1	7	4	32	83	0.90	3	H
		Variation costs	0	7	4	37	79	0.90	3	H
3	*Consultant (Designers) Specific Factors*	Design firm's damaged reputation	5	9	7	37	69	0.85	8	H
		Design firm's time and profit erosion	2	11	12	78	24	0.77	14	H-M
		Designer's exposure to liability	3	11	8	58	47	0.81	11	H
		Decrease in designer's administration time	4	8	12	51	52	0.82	10	H
4	*Client-Consultant-Contractor Specific Factors*	Frustration on stakeholders	3	8	1	51	64	0.86	7	H
		Lack of concentration on other projects	3	13	5	88	18	0.77	14	H-M
		Financial loss	0	8	4	37	78	0.89	4	H
		Wastages of resources	1	7	7	39	73	0.88	5	H
		Inconveniences	1	7	14	68	37	0.81	11	H
		Personal injury and sickness	5	9	19	67	27	0.76	15	H-M
		Claims	1	6	9	30	81	0.89	4	H
		Disputes or Conflict among parties	5	8	6	30	78	0.86	7	H
		Inaccurate estimates	2	10	2	31	82	0.89	4	H
		Higher margins in bids	1	13	2	48	63	0.85	8	H
		Ambiguities	1	11	6	76	33	0.80	12	H
		Frequent Request for Information (RFI)	1	12	18	63	33	0.78	13	H-M
		Creating animosity on site	4	10	23	68	22	0.75	16	H-M
		Strain on contractors and subcontractors	2	8	17	72	28	0.78	13	H-M
		Exploitation of errors in the contract document by contractors	0	10	13	66	38	0.81	11	H
		Frequent change orders	3	9	10	64	41	0.81	11	H
		Design changes	3	11	2	36	75	0.87	6	H
		Litigation in construction projects	1	12	3	50	61	0.85	8	H

The ranking of the most important factors is presented in Tables 7 and 9 while the least important factors are presented in Tables 8 and 10. The findings and discussions are presented in the following sub-sections.

4.1 Impacts of Poor-Quality Design Documentation on Project Delivery

The ranking of variables on the impact of poor design documentation quality is presented in Table 2 based on the RII of the factors. The ranking involves a total of 36 micro factors in 4 macro groups. These groups are; project-specific-factors; client specific-factors, consultant-specific factors and client-consultant-contractor-specific factors. The group ranking based on the mean RII of individual factors is presented in Table 3. This placed project-specific factors in 1st place with a mean RII of 0.89; client-specific factors ranked 2nd with a mean RII of 0.87; client-consultant-contractor-specific factors ranked 3rd with a mean RII of 0.83; and consultant-specific factors ranked 4th with a mean RII of 0.81. However, all 4 groups had mean RII values within 0.8≤RII≤1 indicating high significance of all the factors.

The most important group of factors that impacts project delivery is project-specific factors as presented in Table 3. This group consists of the top 5 ranking of factors as presented in Table 2. These factors include; late completion of projects; rework; project abandonment; structural collapse; and shoddy works. All these factors had RII values between 0.85 - 0.92 and falls within 0.8≤RII≤1 which indicates their high importance. They represent the impact of poor design documentation quality on project delivery. However, earlier researches indicated that poor design documentation quality may result in project delays; generation of rework; project abandonment; structural collapse; (Agbaxode et al., 2021*a*; Shoar and Payan, 2021; Abdallah et al*.,* 2018; Hughes and Thorpe, 2014; Sunday and Afolarin, 2013) and shoddy works (Philips-Ryder et al., 2013; Lopez et al., 2010). This is consistent with the results of this study.

Client specific factors group is the second most important group as presented in Table 3. This group consists of factors such as; project cost overrun; variation costs; project owners' dissatisfaction; and lack of confidence in designers as presented in Table 2.

Table 3. Mean RII and ranking of groups on Impact

Macro Factors	RII	Rank	IL
Project Specific Factors	0.89	1	H
Client Specific Factors	0.87	2	H
Client-Consultant-Contractor Factors	0.83	3	H
Consultant (Designers) Specific Factors	0.81	4	H

All these factors had RII values between 0.82 - 0.90 which falls within 0.8≤RII≤1 indicating high importance. This is consistent with earlier researches which asserts that poor design documentation quality may lead to project cost overrun (Shoar and Payan, 2021; Hughes and Thorpe, 2014; Ramabodu and Verster, 2013; Love et al., 2010; Mohammed, 2007); variation costs (Philips-Ryder et al., 2013; Love et al., 2010); and dissatisfaction by project owners (Sunday and Afolarin, 2013).

The third group of factors based on the ranking in Table 3 is client-consultant-contractor-specific factors. Factors in this group include; financial loss; claims; inaccurate estimates; wastages of resources; disputes or conflict among parties; and higher margins in bids as presented in Table 2. However, all these factors had RII values between 0.80 - 0.89 which are within 0.8≤RII≤1 indicating high importance. Out of a total of 18 factors in this group, 5 factors had RII values within 0.6≤RII≤0.8 indicating high-medium importance as presented in Table 7 as least important factors. However, all the other factors had RII values within 0.8≤RII≤1 indicating high importance. These findings are consistent with earlier studies which concluded that poor design documentation quality may result in financial loss and frustration (Sunday and Afolarin, 2013); claims; disputes among parties and litigation (Abdallah et al., 2018; Philips-Ryder et al., 2013; Laryea, 2011; Lopez et al., 2010; Love et al., 2010); wastages of resources (Philips-Ryder et al., 2013; Sunday and Afolarin, 2013); inaccurate estimates; and higher margins in bids (Abdallah et al., 2018; Laryea, 2011; Mohammed, 2007).

The fourth group of factors is consultant (designers) specific factors and consists of 4 factors which are; design firm's damaged reputation; decrease in designer's administration time; designer's exposure to liability; and design firm's time and profit erosion as presented in Table 2. However, in exception of design firm's time and profit erosion which had an RII value of 0.77 which is within 0.6≤RII≤0.8 indicating high-medium importance as presented in Table 7 as least important factors, all the other factors had RII values between 0.81 - 0.85 which are within 0.8≤RII≤1 indicating high importance. These findings are consistent with earlier studies which posit that poor design documentation quality may result in design firm's damaged reputation, schedule and profit erosion including consultants' exposure to liability (Abdallah et al., 2018; Sunday and Afolarin, 2013).

4.2 Strategies Aimed at Improving the Quality of Design Documentation

Table 5 presents the ranking of factors on strategies to improve design documentation quality. This involves 56 micro factors in 2 main groups which are project-team-specific factors and client-specific factors.

The ranking of the groups based on the mean RII of individual factors in each group is presented in Table 4. This placed client-specific factors 1st with a mean RII of 0.82; and project-team-specific factors 2nd with a mean RII of 0.80. However, the 2 groups had mean RII values within 0.8≤RII≤1 indicating high importance. Therefore, these factors indicate significant strategies to enhance design documentation quality in practice.

The most important group of strategies to enhance design documentation quality is client-specific factors as presented in Table 4. This group consists of factors that admonish clients' to ensure; improved collaboration between architectural and engineering design disciplines; specialists' involvement in design planning and processing of works; day-to-day management of the project; and preparation of detailed design as presented in Table 5. All these factors had RII values between 0.80 - 0.88 which are within 0.8⩽RII⩽1 indicating high importance. Out of a total of 13 factors in this group, 5 factors had RII values within 0.6⩽RII⩽0.8 indicating high-medium importance

as presented in Table 9 as least important factors. However, all the remaining 8 factors had scores within 0.8⩽RII⩽1 which indicates high importance. These findings confirm earlier studies on strategies to improve design documentation quality that; architectural and engineering design disciplines should collaborate (Philips-Ryder et al., 2013); specialists' involvement in design planning and processing (Agbaxode et al., 2021*a*; 2020; Delgado-Hernandez and Aspinwall, 2008); preparation of detailed design and day-to-day management of the project (Ismail et al., 2016; Delgado-Hernandez and Aspinwall, 2008).

Table 4. Mean RII and ranking of groups on Strategies

Macro Factors	RII	Rank	IL
Client Specific Factors	0.82	1	H
Project Team Specific Factors	0.80	2	H

Project-team-specific factors group ranked 2nd as presented in Table 4. These factors include; improvement in collaboration between architectural and engineering design disciplines; specialists' involvement in design planning and processing; encouraging designers to partner with other designers; accountability of design consultants; and increased design documentation fee allowances as presented in Table 5. All these factors had RII values between 0.81 - 0.92 which are within 0.8≤RII≤1 indicating high importance. Out of a total of 43 factors in this group, 25 factors had RII values within 0.6≤RII≤0.8 indicating high-medium importance as presented in Table 9 as least important factors. However, all the remaining 18 factors had scores within 0.8≤RII≤1 indicating high importance.

These findings are consistent with earlier studies which indicated that to improve design documentation quality, there must be an improvement in the collaboration between architectural and engineering design disciplines (Philips-Ryder et al., 2013); specialists' should be involved in design planning and processing (Delgado-Hernandez and Aspinwall, 2008); designers should partner with other designers (Agbaxode et al., 2021*a*; Agbaxode et al., 2020; Mohammed, 2007); accountability of design consultants and increased design documentation fee allowances (Tilley et al., 2002).

Table 5. Strategies aimed at improving design documentation quality

S/N	Macro Factors	Micro Factor Codes	Respondent Scores					RII	Rank	IL
			NI	I	NVI	VI	HI			
1	***Project Team Specific Factors***	Increased design documentation fee allowances	3	10	2	38	74	0.87	5	H
		Increased design time allowance	0	11	11	76	29	0.79	13	H-M
		Design documentation coordination	0	11	6	48	62	0.85	7	H
		Design review management	0	11	5	54	57	0.85	7	H
		Independent Reviews	5	7	5	48	62	0.84	8	H
		Accountability of design consultants	0	9	5	37	76	0.88	4	H
		Constructability	1	11	3	37	75	0.87	5	H
		Increased constructability education	0	9	5	62	51	0.84	8	H
		Increased quality control	0	10	5	74	38	0.82	10	H
		Setting minimum quality and service standards	1	9	9	56	52	0.83	9	H
		Increased documentation standardization	3	8	3	52	61	0.85	7	H
		Partnering	4	6	2	77	38	0.82	10	H
		Designers should also be encouraged to partner with other designers while preparing construction documents	3	7	1	31	85	0.9	3	H
		Concurrent engineering	3	8	3	76	37	0.81	11	H
		Electronic Document Management systems (EDM)	1	10	16	82	18	0.77	15	H-M
		Red-Green-Yellow checking technique	4	7	45	50	21	0.72	19	H-M
		The REDICHECK method	4	7	47	54	15	0.71	20	H-M
		The principle of single statement	0	14	45	53	15	0.71	20	H-M
		Sequencing of work process	0	12	30	77	8	0.73	18	H-M
		Taguchi approach (quality by design)	4	7	38	58	20	0.73	18	H-M
		Developing a corporate memory	1	7	47	56	16	0.72	19	H-M
		Value management	1	11	26	67	22	0.75	17	H-M
		Quality function deployment	0	10	25	71	21	0.76	16	H-M
		Improving working conditions and procedures	0	10	26	65	26	0.77	15	H-M
		Build more error tolerance into the system	4	8	21	77	17	0.75	17	H-M
		Establishment of oversight and monitoring committee	0	12	21	72	22	0.76	16	H-M
		Procedural compliance	0	12	25	74	16	0.75	17	H-M
		Self-check practice	0	11	23	70	23	0.77	15	H-M
		Independent verification	1	8	28	70	20	0.76	16	H-M
		Three-way communication strategy	0	12	18	65	32	0.78	14	H-M
		Good human factor engineering	0	9	16	83	19	0.78	14	H-M
		Job relevant training and practice	0	13	19	70	25	0.77	15	H-M
		Improve overall system performance	0	8	16	85	18	0.78	14	H-M
		Provide ways to detect and correct human errors	0	13	12	82	20	0.77	15	H-M
		Systematic audit to ensure the quality of briefs	0	6	12	77	32	0.81	11	H
		Analysis of Requests for Information (RFI)	0	10	28	68	21	0.76	16	H-M

Table 5. Strategies aimed at improving design documentation quality (continued)

S/N	Macro Factors	Micro Factor Codes	Respondent Scores					RII	Rank	IL
			NI	I	NVI	VI	HI			
1	***Project Team Specific Factors***	Analysis of drawing registers	1	10	26	69	21	0.76	16	H-M
		Measuring the number of revisions to existing drawings	0	10	20	70	27	0.78	14	H-M
		The volume of new drawings issued	0	13	8	86	20	0.78	14	H-M
		Collaboration between architectural and engineering design disciplines should be vastly improved	0	8	2	24	93	0.92	1	H
		Specialists' involvement in design planning and processing of construction works	1	10	3	14	99	0.91	2	H
		Preparation of detailed design	0	12	5	29	81	0.88	4	H
		Day-to-day management of the project	3	9	3	35	77	0.87	5	H
2	***Client Specific Factors***	Clients should always allow adequate time for the preparation of construction documents	1	11	1	52	62	0.86	6	H
		Clients are advised to use the right procurement methods for construction projects	1	8	8	77	33	0.81	11	H
		Provision of elaborate and improved project brief	0	9	9	66	43	0.83	9	H
		Help workers to achieve their social and psychological needs	5	9	20	73	20	0.75	17	H-M
		Systematic audit to ensure the quality of briefs	0	11	8	76	32	0.8	12	H
		Analysis of Requests for Information (RFI)	3	10	20	67	27	0.77	15	H-M
		Analysis of drawing registers	1	11	25	69	21	0.76	16	H-M
		Measuring the number of revisions to existing drawings	0	13	16	71	27	0.78	14	H-M
		The volume of new drawings issued	1	11	20	61	34	0.78	14	H-M
		Collaboration between architectural and engineering design disciplines should be vastly improved	0	13	5	28	81	0.88	4	H
		Specialists' involvement in design planning and processing of construction works	2	11	4	34	76	0.87	5	H
		Preparation of detailed design	2	11	3	43	68	0.86	6	H
		Day-to-day management of the project	2	8	4	41	72	0.87	5	H

4.3 Most and Least Important Impacts of Design Documentation Quality on Project Delivery

The overall ranking of factors on the impact of poor design documentation quality on project delivery is presented in Tables 6 and 7. A total of 30 factors with RII values within $0.8 \leq RII \leq 1$ which indicates high importance are classified as the top most important impacts of poor design documentation quality on project delivery as presented in Table 6 whiles 6 factors with RII values within $0.6 \leq RII \leq 0.8$ indicating high-medium importance are classified as least important factors as presented in Table 7. These factors fall within the 4 macro groups which are; Project Specific Factors (PSF); Client Specific Factors (CSF); Client-Consultant-Contractor Specific Factors (C-C-CSF); and Consultant Specific Factors (Con.SF).

All the factors in Table 6 have a high level of importance in impacting construction project delivery. Some of these factors are late completion of projects; rework; project abandonment; structural collapse; cost overrun; variations; shoddy works; financial loss; and claims.

From Table 7, frequent request for information; strain on all contractors; and design firm's schedule and profit erosion are considered as least important factors that impacts project delivery.

4.4 Most and Least Important Strategies to Improve Design Documentation Quality

The overall ranking of factors on strategies to improve design documentation quality is presented in Tables 8 and 9. A total of 26 factors with RII values within $0.8 \leq RII \leq 1$ which indicates high importance are classified as the top most important strategies as presented in Table 8 whiles 30 factors with RII values within $0.6 \leq RII \leq 0.8$ indicate high-medium importance are classified as least important factors as presented in Table 9. These factors fall within the 2 macro groups which are Project Team Specific Factors (PTSF); and Client Specific Factors (CSF).

5. Conclusion and Recommendation

Efforts toward improving the quality of design documentation can be enhanced if the impact on project delivery is known. While there are projects that are delivered without significant design documentation challenges, there are also numerous projects bedeviled with poor quality design documentation with corresponding negative impacts on project delivery. Therefore, this study aims to empirically assess the impacts of poor design documentation quality on project delivery and quality improvement strategies. The assessment involves the determination of RII values of each factor based on questionnaire responses and further ranks the factors accordingly. A total of 92 factors consisting of 36 factors on the impact of poor design documentation quality on project delivery and 56 factors on strategies that aim to improve design documentation quality were used. From Table 8, some of the most important strategies include improving collaboration between architectural and engineering design disciplines; specialists' involvement in design planning and processing; designers partnering with other designers; and accountability of design consultants. From Table 9, some of the least important strategies include increased design time allowance; three-way communication strategy; good human factor engineering; and improving overall system performance.

Table 6. Most important impacts of poor design documentation quality on project delivery

S/N	Top 30 Most important impacts of poor design documentation quality	Macro Group	RII	Rank	IL
1	Late completion of project or delay	PSF	0.92	1	H
2	Generation of Rework	PSF	0.91	2	H
3	Project abandonment	PSF	0.90	3	H
4	Structural collapse	PSF	0.90	3	H
5	Project cost overrun	CSF	0.90	3	H
6	Variation costs	CSF	0.90	3	H
7	Shoddy works	PSF	0.89	4	H
8	Dissatisfaction by project owners	CSF	0.89	4	H
9	Financial loss	C-C-CSF	0.89	4	H
10	Claims	C-C-CSF	0.89	4	H
11	Inaccurate estimates (Overestimation)	C-C-CSF	0.89	4	H
12	Deterioration of buildings and Defects	PSF	0.88	5	H
13	Constraining project efficiency	PSF	0.88	5	H
14	Low productivity on construction projects	PSF	0.88	5	H
15	Wastages of resources	C-C-CSF	0.88	5	H
16	Design changes	C-C-CSF	0.87	6	H
17	Frustration on stakeholders	C-C-CSF	0.86	7	H
18	Disputes or Conflict among parties	C-C-CSF	0.86	7	H
19	Higher margins in bids	C-C-CSF	0.85	8	H
20	Litigation in construction projects	C-C-CSF	0.85	8	H
21	Contributing to poor service quality	PSF	0.85	9	H
22	Design firm's damaged reputation	Con.SF	0.85	9	H
23	Discourages investment	CSF	0.84	10	H
24	Lack of confidence in consultants	CSF	0.82	11	H
25	Decrease in designer's administration time	Con.SF	0.82	11	H
26	Inconveniences	C-C-CSF	0.81	11	H
27	Exploitation of errors in the contract document by contractors	C-C-CSF	0.81	11	H
28	Frequent change orders	C-C-CSF	0.81	11	H
29	Designer's exposure to liability	Con.SF	0.81	12	H
30	Ambiguities	C-C-CSF	0.80	12	H

Table 7. Least important impacts of poor design documentation quality on project delivery

S/N	Least important impacts of poor design documentation quality	Macro Group	RII	Rank	IL
1	Frequent Request for Information (RFI)	C-C-CSF	0.78	13	H-M
2	Strain on contractors and subcontractors	C-C-CSF	0.78	13	H-M
3	Lack of concentration on other projects	C-C-CSF	0.77	14	H-M
4	Design firm's time and profit erosion	Con.SF	0.77	15	H-M
5	Personal injury and sickness	C-C-CSF	0.76	15	H-M
6	Creating animosity on site	C-C-CSF	0.75	16	H-M

Table 8. Most important strategies aimed at improving design documentation quality

S/N	Top 26 Most important strategies aimed at improving the quality of design documentation	Macro Group	RII	Rank	IL
1	Collaboration between architectural and engineering design disciplines should be vastly improved	PTSF	0.92	1	H
2	Specialists' involvement in design planning and processing of construction works	PTSF	0.91	2	H
3	Designers should also be encouraged to partner with other designers while preparing construction documents	PTSF	0.9	3	H
4	Accountability of design consultants	PTSF	0.88	4	H
5	Preparation of detailed design	PTSF	0.88	4	H
6	Collaboration between architectural and engineering design disciplines should be vastly improved	CSF	0.88	4	H
7	Increased design documentation fee allowances	PTSF	0.87	5	H
8	Constructability	PTSF	0.87	5	H
9	Day-to-day management of the project	PTSF	0.87	5	H
10	Specialists' involvement in design planning and processing of construction works	CSF	0.87	5	H
11	Day-to-day management of the project	CSF	0.87	5	H
12	Preparation of detailed design	CSF	0.86	6	H
13	Clients should always allow adequate time for the preparation of construction documents	CSF	0.86	6	H
14	Design documentation coordination	PTSF	0.85	7	H
15	Design review management	PTSF	0.85	7	H
16	Increased documentation standardization	PTSF	0.85	7	H
17	Independent Reviews	PTSF	0.84	8	H
18	Increased constructability education	PTSF	0.84	8	H
19	Setting minimum quality and service standards	PTSF	0.83	9	H
20	Provision of elaborate and improved project brief	CSF	0.83	9	H
21	Increased quality control	PTSF	0.82	10	H
22	Partnering	PTSF	0.82	10	H
23	Concurrent engineering	PTSF	0.81	11	H
24	Systematic audit to ensure the quality of briefs	PTSF	0.81	11	H
25	Clients are advised to use the right procurement methods for construction projects	CSF	0.81	11	H
26	Systematic audit to ensure the quality of briefs	CSF	0.8	12	H

Table 9. Least important strategies to improve the quality of design documentation

S/N	30 Least important strategies aimed at improving design documentation quality	Macro Group	RII	Rank	IL
1	Increased design time allowance	PTSF	0.79	13	H-M
2	Three-way communication strategy	PTSF	0.78	14	H-M
3	Good human factor engineering	PTSF	0.78	14	H-M
4	Improve overall system performance	PTSF	0.78	14	H-M
5	Measuring the number of revisions to existing drawings	PTSF	0.78	14	H-M
6	The volume of new drawings issued	PTSF	0.78	14	H-M
7	Measuring the number of revisions to existing drawings	CSF	0.78	14	H-M
8	The volume of new drawings issued	CSF	0.78	14	H-M
9	Electronic Document Management systems (EDM)	PTSF	0.77	15	H-M
10	Improving working conditions and procedures	PTSF	0.77	15	H-M
11	Self-check practice	PTSF	0.77	15	H-M
12	Job relevant training and practice	PTSF	0.77	15	H-M
13	Provide ways to detect and correct human errors	PTSF	0.77	15	H-M
14	Analysis of Requests For Information (RFI)	CSF	0.77	15	H-M
15	Quality function deployment	PTSF	0.76	16	H-M
16	Establishment of oversight and monitoring committee	PTSF	0.76	16	H-M
17	Independent verification	PTSF	0.76	16	H-M
18	Analysis of Requests for Information (RFI)	PTSF	0.76	16	H-M
19	Analysis of drawing registers	PTSF	0.76	16	H-M
20	Analysis of drawing registers	CSF	0.76	16	H-M
21	Value management	PTSF	0.75	17	H-M
22	Build more error tolerance into the system	PTSF	0.75	17	H-M
23	Procedural compliance	PTSF	0.75	17	H-M

Table 9. Least important strategies to improve the quality of design documentation (continued)

S/N	30 Least important strategies aimed at improving design documentation quality	Macro Group	RII	Rank	IL
24	Help workers to achieve their social and psychological needs	CSF	0.75	17	H-M
25	Sequencing of work process	PTSF	0.73	18	H-M
26	Taguchi approach (quality by design)	PTSF	0.73	18	H-M
27	Red-Green-Yellow checking technique	PTSF	0.72	19	H-M
28	Developing a corporate memory	PTSF	0.72	19	H-M
29	The REDICHECK method	PTSF	0.71	20	H-M
30	The principle of single statement	PTSF	0.71	20	H-M

5.1 Impacts of Poor Design Documentation Quality on Project Delivery

The ranking presented 30 most important factors on the impact of poor design documentation quality on project delivery that were highly ranked and 6 least important factors that were high-medium ranked. Some of the top highly ranked factors include; late completion of projects; rework; project abandonment; structural collapse; cost overrun; variation costs; shoddy works; financial loss; claims; inaccurate estimates; low productivity; wastages of resources; design changes; disputes or conflict among parties; higher margins in bids; and litigation. The least important factors include: frequent request for information (RFI); strain on all contractors; design firm's schedule and profit erosion; and creating animosity on site. However, these factors are also important due to their negative impacts on project delivery.

5.2 Strategies to Improve Design Documentation Quality

The ranking presented 26 most important (highly ranked) factors on strategies that aim to improve design documentation quality and 30 least important factors that were high-medium ranked. Some of the top highly ranked factors include; improving collaboration between architectural and engineering design disciplines; specialists' involvement in design planning and processing of works; encouraging designers to partner with other designers; accountability of design consultants; preparation of detailed design; and increased design documentation fee allowances. Some of the factors that are considered least important include: increase design time allowance; three-way communication strategy; improve overall system performance; the number of revisions to drawings; and the quantum of new drawings issued. However, these factors also contribute toward improving design documentation quality.

This study presents pragmatic data and significant insight to industry practitioners, researchers and academics on the impacts of poor design documentation quality on project delivery including quality improvement strategies. This will help in taking steps during project delivery towards mitigating the effect of these impacts by working towards an improvement in design documentation quality. Despite the significant contributions of this study, one main limitation is the objective nature of the study based on quantitative data. Future studies should consider the subjective views of industry professionals on the aim by conducting a qualitative study. As a recommendation, future studies should build on this study and develop a robust framework that will aim to improve design documentation quality within the existing project delivery methods.

Author Contributions

Peter D.K. Agbaxode conceived the research and contributes to conceptualization, methodology, data collection and analysis, draft preparation, and manuscript editing. Ehsan Saghatforoush contributed to draft preparation, manuscript editing, and supervision. Sitsabo Dlamini contributed to draft preparation, manuscript editing, and supervision. All authors have read and agreed with the manuscript before its submission.

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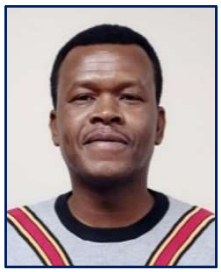

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