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Measures to Enhance the Use of Geosynthetics for Civil Infrastructure Projects: An Example from Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative impact of each measure. It employed the Delphi technique, and a structured questionnaire aided the data collection from 15 expert panellists. At least a good consensus was reached in the views of the expert panellists regarding 14 measures to enhance the use of geosynthetics in Ghana after two rounds of a Delphi survey. Out of the 14 measures, there was a strong consensus in the views of the expert panellists regarding 3 measures as they recorded median values within the range (VHI: 9.00-10.00) signifying very high impact. These measures were, readily availability of geosynthetic products in the market, availability of design manuals for geosynthetics design, and educating construction practitioners on geosynthetics options for meeting their infrastructure needs. A good consensus was attained in the views of the expert panellists for the remaining 11 measures as they recorded median scores within the range (HI: 7.00-8.99) signifying high impact. Moreso, 2 out of the 14 measures were unique to this study in Ghana: setting up of a geosynthetic think tank to advocate for the use of geosynthetics, and promoting geosynthetics usage in the manifestos of political parties. In terms of relative impact index ranking, readily availability of geosynthetic products in the market with RII score of 0.91 ranked 1st whereas increase geosynthetics education and exposure for prospective and practising civil engineers with RII of 0.79 ranked 14th. This study is unique in that it applies the Delphi

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technique and empirically establishes the measures to enhance the use of geosynthetics for civil infrastructure projects giving an example from Africa, specifically Ghana which hitherto was not in existence.

Keywords: Civil infrastructure projects; delphi; geosynthetics; Ghana; survey.

1. INTRODUCTION

Geosynthetics are polymeric materials used to enhance, improve or stabilize soil, rock, earth or any geotechnical substance as an integral part of civil infrastructure projects [1-3]. They come in the form of strips, straps, sheets, or three-dimensional structures [4-5]. The root of the use of geosynthetics could be traced to the days of the Pharaohs in ancient Egypt when natural geosynthetics made of jute, wood, and raffia, among others, were used to improve soil conditions in road works [6]. However, the advent of polymer in the 1960s reinvented geosynthetic use as more sustainable and longer-lasting polymeric materials were then used for the manufacturing of geosynthetics [7-8].

In recent times, there is even in existence intelligent geosynthetics which makes it possible to monitor the performance of civil infrastructure projects that have intelligent geosynthetics as an integral component. Intelligent geosynthetics are geosynthetics with integrated chips and sensors for measuring strains, temperature and other environmental conditions [2]. Geosynthetics have a wide range of applications in hydraulics, environmental, construction, transportation, and geotechnical engineering within the broad civil engineering discipline. Specific civil infrastructure projects that applied geosynthetics include landfill projects, dams, harbours, railways, and pipe projects [5] and [9] with road projects being the civil infrastructure projects with the most applications of geosynthetics [9]. There are nine main types of geosynthetics namely geotextiles, geonets, geogrids, geomembranes, geosynthetic clay liners, geofoams, geopipes, geocomposites, and geocells [5,10], with geotextiles and geomembranes being the most applied geosynthetics [11-12]; followed by geogrids [12]. The primary functions of geosynthetics include reinforcement, stabilization, erosion control, filtration, fill material, containment, drainage, separation, and protection [3-4,11]. The use of geosynthetics reduces the use of natural materials [13-14]. It contributes to the delivery of low-cost and time-efficient projects [3,13,15-16], improves slope stability, and generally modifies the conditions of the soil [4,17-18]. Furthermore, the use of geosynthetics contributes to carbon reduction [13]. In the United Kingdom (UK), WRAP (Waste and Resources Action Programme), a non-profit organization which is sponsored by the UK government, has been set up to help promote, among others, the sustainable benefits of geosynthetics [13,19]. In 2010, WRAP produced a report titled 'Sustainable Geosystems in Civil Engineering Applications' to demonstrate the use of geosynthetics to reduce the environmental impact of construction projects [13,19].

Though the comparative advantages of the use of geosynthetics for civil infrastructure projects outweigh the benefits of using traditional alternatives of improving conditions of weak soil for civil infrastructure projects, its patronage is globally low and Africa's usage of geosynthetics was estimated at only 7% in 2021 [4]. Whereas country-specific studies on measures to enhance the use of geosynthetics from the developed world such as the UK and the USA and Asia (specifically India) are known; there is a lack of a country-specific study from Africa that gives an account of the measures to enhance the use of geosynthetics for civil infrastructure projects. Hence, the relevance of this current study as it gives an account of measures to enhance the use of geosynthetics by providing an example from Ghana, a country in Africa. In Ghana, studies in the past have unravelled the constraints to the use of geosynthetics [20], and the extent of application of geosynthetics to civil infrastructure projects [21], among others. None of the studies has established the measures to enhance the use of geosynthetics for civil infrastructure projects.

Furthermore, studies in the past have predominantly employed surveys and experimental research designs in studying geosynthetics (see [3,9,13,20-21]). Whereas none of the studies in the past has ever employed the Delphi technique in a geosynthetic study. Hence, this current study's uniqueness also lies in the use of the Delphi technique to establish measures to enhance the use of geosynthetics for civil infrastructure

projects. The Delphi technique, among others, has strength in establishing consensus in the views of expert panellists regarding an issue under investigation [22-23]. Hence, the Delphi technique was found appropriate in the realisation of the aim of the study. The aim of this current study is to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative impact of each measure.

The specific objectives that governed the study were:

- to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana,
- to determine the relative impact of each of the measures for enhancing the use of geosynthetics for civil infrastructure projects in Ghana.

Civil infrastructure projects are the basic systems including but not limited to roads, buildings, and dams, that help society to function [21].

2. MEASURES TO ENHANCE THE USE OF GEOSYNTHETICS FOR CIVIL INFRASTRUCTURE PROJECTS: A SURVEY OF PREVIOUS STUDIES

Regarding the measures to enhance the use of geosynthetics for civil infrastructure projects, some country-specific studies have been advanced in the past. According to [11] and [13] product availability, and content provision in existing curricula are critical in enhancing the level of use of geosynthetics. The [24] mentioned that the provision of laboratories for testing geosynthetics will enhance the use of geosynthetics as designers will be certain of the design strength of their specifications. Furthermore, [11] and [13] informed that educating clients and construction industry practitioners on geosynthetics increases awareness and translates into enhancing the use of geosynthetics. Again, the development of country-specific standards, investment in geosynthetic-related research, the inclusion of geosynthetics in the standard forms of contracts, and publishing standard schedule of rates for geosynthetics culminate in promoting the use of geosynthetics [11].

According to [13] promotional literature, training and workshops, presentations on geosynthetics at conferences, geosynthetics exhibitions/ events, corporate entertainment, social media advertisement, and setting up geosynthetic technical committees to promote usage are all measures that enhance the use of geosynthetics. Likewise, [25] asserted that publicizing the comparative advantages geosynthetics have over traditional alternatives creates awareness and enhances the use of geosynthetics as clients prioritize the use of geosynthetics over traditional alternatives. Similarly, providing training and refresher courses in geosynthetics to training providers will enhance the use of geosynthetics [26]. Accordingly, [13] affirmed this view by advocating for the institution of educating the educator programme in the UK to enhance the use of geosynthetics. Again, the institution of training programmes for academics is essential in enhancing the use of geosynthetics [27-28].

In a study in the USA, measures to enhance the use of geosynthetics included the establishment of proper mechanisms for geosynthetics applications, the availability of a manual on proper methods for construction and quality control measures for geosynthetics usage [10]. Development of quality assurance tests and procedures for geosynthetics usage, availability of design manuals and training courses, increase in geosynthetic education and exposure for prospective and practising civil engineers, the inclusion of geosynthetics in every civil engineering undergraduate programme, and development of regulatory and national code bodies to develop generic specifications were found to be measures to enhance the use of geosynthetics [28].

Thus from the review of the few available literature, measures to enhance the use of geosynthetics could be summarized as: readily availability of geosynthetic products in the market, provision of geosynthetics content in existing curricula for civil and allied programmes in institutions of higher learning, educating clients on geosynthetics options for meeting their infrastructure needs, educating construction practitioners on geosynthetics options for meeting their infrastructure needs, development of country-specific standards for geosynthetics application, investment in geosynthetic-related research, promoting geosynthetics through training and workshops, promoting geosynthetics usage through the availability of manuals on proper methods for construction, promoting geosynthetics usage through the development of quality control measures for geosynthetics usage, availability of design manuals for geosynthetics design, increase geosynthetics education and exposure

for prospective and practising civil engineers, and institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons. These measures formed the basis for this current study in Ghana.

3. METHODOLOGY

This study employed the Delphi technique in establishing consensus in the views of expert panellists regarding measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana. Delphi is applicable to both qualitative and quantitative research [22-23]. It involves the use of a structured questionnaire in soliciting views from expert panellists through rounds of questionnaire surveys [22-23]. This study employed the Delphi technique and adapted the detailed Delphi process outlined by [29] (see Fig. 1). The first step of the Delphi process was a literature review. This helped in identifying the measures to enhance the use of geosynthetics as advanced in previous, which formed the basis for this study's questionnaire. The second step was the selection of experts to constitute the panel for the Delphi study. The key stakeholders within the geosynthetics chain comprised academics, researchers, manufacturers, suppliers, designers, contractors [28], and the government [11]. Since each stakeholder within the geosynthetics chain has a unique function to play in the promotion of geosynthetic usage, the Delphi panel of experts were carefully selected to represent a broad spectrum of opinion on the issue being investigated (see [23,29]). Hence, they were drawn from industry and academia. According to [29] critical to the selection of experts is the theoretical and practical knowledge of the experts. Hence, the checklist in appendix 1 aided in prequalifying the experts on the Delphi panel. Initially, eighteen (18) experts freely responded in the affirmative via separate emails and 'WhatsApp' chat to participate in the Delphi survey. However, only fifteen (15) experts participated in all the two rounds of the survey. The Delphi process ended after round two when a consensus was attained in the views of the experts regarding the measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana. The sample size of 15 experts for the study was based on the assumption that the sample size for a Delphi study is not dependent on a statistical sample which ought to be representative of a population instead, it brings together experts to share their knowledge in relation to the subject under investigation [22-23]. Thus, based on recommendations from previous studies that employed the Delphi technique, the 15 expert panellists for this current study were deemed adequate. According to [22-23], 10 to 15 panellists are sufficient for a Delphi study. Afterwards, the instructions and the questionnaires for round one of the Delphi survey were sent to the experts (see Appendices 2 and 3). 15 experts responded to both round one and two of the survey.

Relating the demographic characteristics of the experts with the checklist for selecting experts (see appendix 1) revealed that the minimum obtained mark for the educational level was 2 points (Bachelor's degree). All experts belonged to a professional association thus the minimum obtained mark was 1 point whereas, the minimum obtained mark for work experience was 2 points (6–10 years). A minimum required mark of 5 points was required of an expert before becoming part of the panel of experts (see appendix 1). Therefore, since the minimum mark obtained by the experts summed up to 5 points the experts were deemed fit for the Delphi study. The questionnaire for the study was developed based on the findings of the critical literature review this study undertook. The quality of the questionnaire (clarity, duration to complete questionnaire, among others) was tested through a pilot study. Feedback obtained was incorporated before the final set of questionnaires for the study was produced.

In analysing and determining consensus in experts' responses the mean, median, standard deviation, interquartile deviation (IQD), relative impact index have been used in previous studies. At least one of the statistics has been used in estimating consensus in previous studies. Hence, this study adopted a combination of the median, standard deviation, interquartile deviation (IQD), and relative impact index in determining consensus. A similar approach was used by [30] and even in quite recent studies (see [22,29,31]). Thus, in this study consensus was measured by:

1. Strong consensus - median 9-10, relative impact index 0.80-1.00, interquartile deviation (IQD) ≤1;
2. Good consensus - median 7-8.99, relative impact index 0.60-0.79, IQD≥1,1≤2; and
3. Weak consensus - median ≤ 6.99, relative impact index ≤0.59 and IQD≥2,1≤3.

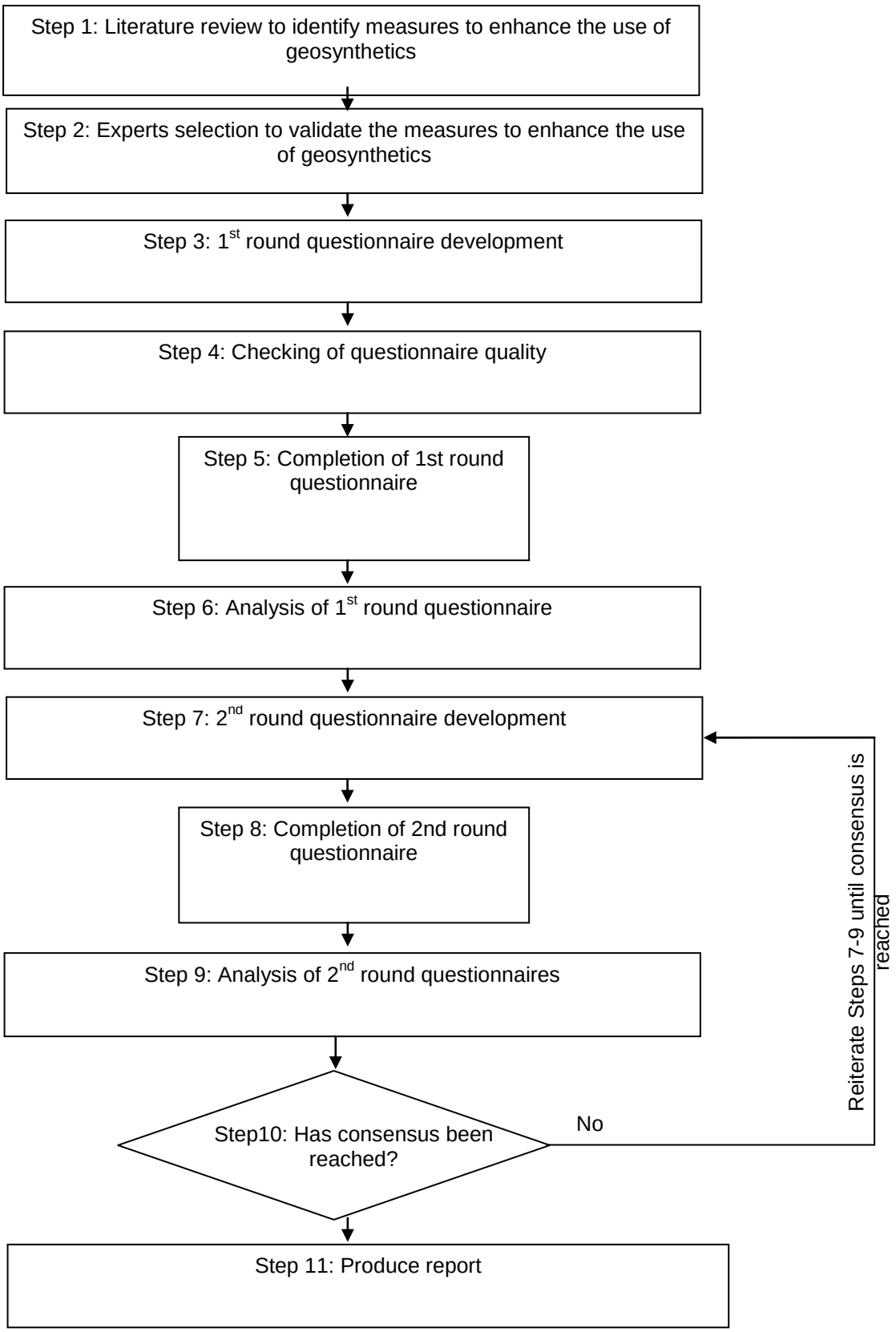

Fig. 1. Diagram of the delphi process
Source: Adapted from Aigbavboa (2014)

Table 1. Respondents' demographic characteristics

Respondents' demographic characteristics	Frequency(n=15)	Percentage (%)
Place of work		
Academic institutions	6	40.0
Research institutions	2	13.3
Suppliers	2	13.3
Consultants	2	13.3
Contractors	3	20.0
Total	**15**	**100**
Level of Education		
Bachelor's degree	1	6.7
Master's degree	11	73.3
PhD	3	20.0
Total	**15**	**100**
Professional affiliation		
Institution of Engineering and Technology, Ghana	6	40.0
Ghana Institution of Engineering	4	26.7
Ghana Institution of Surveyors	2	13.3
Ghana Institute of Architects	3	20.0
Total	**15**	**100**
Work experience		
5 years or less	0	0.0
6-10 years	4	26.7
11-15 years	6	40.0
16-20 years	2	13.3
Over 20 years	3	20.0
Total	**15**	**100**

This was based on a 10-point impact scale where 1 and 2 represented no impact; 3 and 4 represented low impact; 5 and 6 represented medium impact; 7 and 8 represented high impact; 9 and 10 represented very high impact. In addressing the challenge of validity, reliability, and generalization of results associated with qualitative studies [22 asserted that validity, reliability and generalization of Delphi findings are anchored on the rigorousness of the data collection process [22]. In view of this, a rigorous methodological process was adapted for the study (see Fig. 1). Also, internal validity was ensured through constant communication with the experts on an individual basis and offering the experts the opportunity to freely maintain or effect changes to their responses and giving reasons for the latter. A structured questionnaire was used in soliciting data from the panel of experts (see [29,32]). After each round of the Delphi survey, a statistical estimate of the experts' views was calculated and analysed using the standard deviation, interquartile deviation, median, and relative impact index. The identity of the experts was kept confidential in line with the ethical considerations of a Delphi study [22,29,32].

4. RESULTS

4.1 Delphi Round One Results

Round one of the Delphi survey was to validate, based on the views of the expert panellists, the measures to enhance the use of geosynthetics for civil infrastructure projects as identified through the literature review. Also, experts were offered the opportunity to suggest new measures that were not captured on the questionnaire. The outcome of the round one of the Delphi survey has been presented in Table 2a and Table 2b. Table 2b is a continuation of Table 2a. In all, 12 measures identified from the literature review were validated by the expert panellist during round one of the Delphi survey to be of impact in enhancing the use of geosynthetics in Ghana whereas two new measures were also suggested by the expert panellists to be of impact in enhancing the use of geosynthetics in Ghana. The two were setting *up a geosynthetic think tank to advocate for the use of geosynthetics,* and *promoting geosynthetics usage in the manifestos of political parties.* Thus, a total of 14 measures were identified to be of impact in enhancing the use of geosynthetics in Ghana. Out of the 14

measures, 3 recorded very high impact (VHI: 9.00-10.00) whiles the remaining 11 recorded a high impact (HI:7.00-8.00) on enhancing the use of geosynthetics in Ghana. The 14 measures formed the basis of the questionnaire for round two of the Delphi survey.

4.2 Delphi Round Two Results

A total of 14 measures, with their corresponding group medians, were presented to the expert panellists in round two of the Delphi survey. The expert panellists were asked to confirm their views or otherwise regarding the measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana. They were also asked to provide reasons for the change in view or stance if any. According to Table 3, 3 out of the 14 measures, recorded very high impact (VHI: 9.00-10.00) whiles the remaining 11 had a high impact on enhancing the use of geosynthetics in Ghana. Thus, none of the expert panellists changed their stance. As a result, a consensus was reached in the view of the expert panellists. Therefore, the Delphi survey ended after round two.

Table 2 (a). Delphi round one results on measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana

SN	Measures to enhance the use of geosynthetics The use of geosynthetics could be enhanced through:	Median	Interquartile deviation (IQD)
1	readily availability of geosynthetic products in the market	9	0.0
2	provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning	8	1.0
3	educating clients on geosynthetics options for meeting their infrastructure needs	8	1.0
4	educating construction practitioners on geosynthetics options for meeting their infrastructure needs	9	0.0
5	development of country-specific standards for geosynthetics applications	8	1.0
6	investment in geosynthetic-related research	8	1.0
7	promoting geosynthetics through training and workshops	8	1.0

Table 2 (b). Delphi round one results on measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana

SN	Measures to enhance the use of geosynthetics The use of geosynthetics could be enhanced through :	Median	Interquartile deviation (IQD)
8	promoting geosynthetics usage through the availability of manuals on proper methods for construction	8	1.0
9	promoting geosynthetics usage through the development of quality control measures for geosynthetics usage	8	1.0
10	availability of design manuals for geosynthetics design	9	0.5
11	increase geosynthetics education and exposure for prospective and practising civil engineers	8	1.0
12	Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons	8	1.0
13	setting up a geosynthetic think tank to advocate for the use of geosynthetics	8	1.0
14	promoting geosynthetics usage in the manifestos of political parties	8	1.0

Table 3. Delphi round two results on measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana

SN	Measures to enhance the use of geosynthetics	Median	Interquartile deviation (IQD)	Standard deviation	Relative impact index	Relative impact ranking	Remarks
	The use of geosynthetics could be enhanced through:						
1	Readily availability of geosynthetic products in the market	9	0.0	0.00	0.91	1st	Strong consensus
2	Provision of geosynthetics content in existing curricula for civil and allied programmes in institutions of higher learning	8	1.0	0.56	0.79	4th	Good consensus
3	Educating clients on geosynthetics options for meeting their infrastructure needs	8	1.0	0.47	0.77	8th	Good consensus
4	Educating construction practitioners on geosynthetics options for meeting their infrastructure needs	9	0.0	0.23	0.88	2nd	Strong consensus
5	Development of country-specific standards for geosynthetics applications	8	1.0	0.31	0.78	7th	Good consensus
6	Investment in geosynthetic-related research	8	1.0	0.00	0.70	13th	Good consensus
7	Promoting geosynthetics through training and workshops	8	1.0	0.00	0.79	4th	Good consensus
8	promoting geosynthetics usage through the availability of manuals on proper methods for construction	8	1.0	0.00	0.76	10th	Good consensus
9	promoting geosynthetics usage through the development of quality control measures for geosynthetics usage	8	1.0	0.00	0.75	11th	Good consensus
10	availability of design manuals for geosynthetics design	9	0.5	0.89	0.80	3rd	Strong consensus
11	increase geosynthetics education and exposure for prospective and practising civil engineers	8	1.0	0.00	0.69	14th	Good consensus
12	Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons	8	1.0	0.00	0.72	12th	Good consensus
13	setting up a geosynthetic think tank to advocate for the use of geosynthetics	8	1.0	0.55	0.77	8th	Good consensus
14	promoting geosynthetics usage in the manifestos of political parties	8	1.0	0.70	0.79	4th	Good consensus

5. DISCUSSION

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative impact of each measure. 14 measures were identified to be of impact on enhancing the use of geosynthetics in Ghana. Out of the 14 measures, 3 measures recorded very high impact with median scores ranging (VHI: 9.00-10.00) and RII values within 0.80-1.00, thus signifying a strong consensus in the view of the expert panellists regarding these 3 measures and their impact on enhancing the use of geosynthetics in Ghana. These measures were, readily availability of geosynthetic products in the market, availability of design manuals for geosynthetics design, and educating construction practitioners on geosynthetics options for meeting their infrastructure needs. The remaining 11 recorded median scores within the range (HI: 7.00-8.99) signifying a high impact with RII scores within the range (0.60-0.79). Thus, a good consensus was attained in the view of the expert panellists regarding 11 measures and their impact on enhancing the use of geosynthetics for civil infrastructure projects in Ghana. Moreso, 2 of the measures were unique to this study in Ghana. They were setting up a geosynthetic think tank to advocate for the use of geosynthetics and promoting geosynthetics usage in the manifestos of political parties. Though the level of consensus varied among the measures, the respective IQD scores indicated strong consensus with IQD being ≤1.

Ranking by the respective RII scores, readily availability of geosynthetic products in the market with RII score of 0.91 ranked 1st.This was found an essential measure in enhancing the use of geosynthetics [7,11]. Educating construction practitioners on geosynthetics options for meeting their infrastructure needs with RII score of 0.88 ranked 2nd. This was consistent with the earlier findings by [11] and [13] that the use of geosynthetics could be enhanced by educating construction practitioners on geosynthetics options for meeting their infrastructure needs. Availability of design manuals for geosynthetics design with RII of 0.80 ranked 3rd. The availability of design manuals for geosynthetics design was found by [28] to be an essential measure to enhance the use of geosynthetics. Provision of geosynthetics content in existing curricula for civil and allied programmes in institutions of higher learning with RII value of 0.79 ranked 4th. This was consistent with the argument by [7] and [11] that the use of geosynthetics could be enhanced through the provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning. Equally ranking 4th was promoting geosynthetics through training and workshops which recorded RII score of 0.79. According to [13] promoting geosynthetics through training and workshops is an essential measure to enhance the use of geosynthetics.

Furthermore, [25] suggested that through workshops and other media, emphasis should also be laid on publicizing the comparative advantages geosynthetics have over traditional alternatives. Moreso, promoting geosynthetics usage in the manifestos of political parties with RII score of 0.79 ranked 4th. This measure was unique to this study in Ghana only as it was not part of the measures identified through the literature review. Development of country-specific standards for geosynthetics applications with RII score of 0.78 also ranked 7th. According to [11], the factors that affect the use of geosynthetics are country-specific and thus require the development of country-specific standards for geosynthetics applications. Educating clients on geosynthetics options for meeting their infrastructure needs obtained RII score of 0.77 and ranked 8th. This supports the view of [11] and [13] that educating clients on geosynthetics options for meeting their infrastructure needs is an essential measure to enhance the use of geosynthetics. Moreso, setting up a geosynthetic think tank to advocate for the use of geosynthetics obtained RII score of 0.77 and ranked 8th.This measure was unique to this study in Ghana. Promoting geosynthetics usage through the availability of manuals on proper methods for construction with RII score of 0.76 ranked 10th. According to [10] availability of manual on proper methods for construction is essential due to the lack of manuals to aid construction using geosynthetics. Promoting geosynthetics usage through the development of quality control measures for geosynthetics usage with RII score of 0.75 ranked 11th. According to [10] promoting geosynthetics usage through the development of quality control measures for geosynthetics usage is essential measure to enhance the use of geosynthetics.

Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons with RII score of 0.72 emerged 12th. This supports the

assertion by [27-28] that the use of geosynthetics could be enhanced through the institution of training programmes for academics in geosynthetics to inform their delivery of lessons on geosynthetics. Likewise, [26] advocated for the institution of a programme to educate lecturers and facilitators who were found to be incapacitated to offer training in geosynthetics engineering. Investment in geosynthetic-related research obtained RII score of 0.70 and ranked 13th .This was consistent with the view of [11,28] that investment in geosynthetic related research is a sure measure for promoting the use of geosynthetics. Increase geosynthetics education and exposure for prospective and practising civil engineers with RII of 0.79 ranked 14th. This affirms the argument by [28] that the use of geosynthetics could be enhanced through an increase in geosynthetics education and exposure for prospective and practising civil engineers.

6. CONCLUSIONS

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative impact of each measure. In all 14 measures were identified to be of impact on enhancing the use of geosynthetics for civil infrastructure projects in Ghana. Out of the 14 measures 2 were unique to this study in Ghana namely: setting up a geosynthetic think tank to advocate for the use of geosynthetics and promoting geosynthetics usage in the manifestos of political parties. Relatively, readily availability of geosynthetic products in the market with RII score of 0.91 ranked 1st whiles increase geosynthetics education and exposure for prospective and practising civil engineers with RII of 0.79 ranked 14th. This study is unique in that it applied the Delphi technique and empirically established the measures to enhance the use of geosynthetics for civil infrastructure projects giving an example from Africa, specifically Ghana which hitherto was not in existence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

APPENDIX 1: Criteria/checklist for constituting the panel of experts for the Delphi study

Questionnaire items	Possible marks	Maximum expected mark	Minimum expected mark	Minimum obtained marks
Q1. Please indicate your highest level of education				
Higher National Diploma	1 point		1 point	
Bachelor's degree	2 points			2 points
Master's degree	3 points			
Doctoral degree	4 points	4 points		
Q2. Are you a member of any professional body in Ghana				
Yes	1 point	1 point		1 point
No	0 point		0 point	
Q3. Please indicate your years of experience with geosynthetics				
Below 5 years	1 point		1 point	
6 to10 years	2 points			2 points
11 to 15 years	3 points			
Above 15 years	4 points	4 points		
Total points		9 points	2 points	5 points

Note: the minimum obtained mark of 5 points qualified an expert to be part of the Delphi panel

APPENDIX 2: Delphi round one and questionnaire instructions

Base on your knowledge and experience please indicate the extent to which the underlisted measures will be of impact in enhancing the use of geosynthetics in Ghana by placing "X" in the boxes provided against each measure using a 10-point scale? Other measures of enhancing the use of geosynthetics in Ghana that have not been listed could as well be suggested.

No impact		Low imp act		Medium impact		High impact			Very high impact
1	2	3	4	5	6	7	8	9	10

Q1. Please indicate the extent to which the underlisted measures are of impact in enhancing the use of geosynthetics Ghana? 1 =no impact to 10 very high impact

Measures to enhance the use of geosynthetics	From no impact to very high impact									
The use of geosynthetics could be enhanced through :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Readily availability of geosynthetic products in the market									x	
Provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning								X		
Educating clients on geosynthetics options for meeting their infrastructure needs								X		
Educating construction									X	

Measures to enhance the use of geosynthetics	From no impact to very high impact									
The use of geosynthetics could be enhanced through :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
practitioners on geosynthetics options for meeting their infrastructure needs										
development of country-specific standards for geosynthetics application								X		
investment in geosynthetic-related research								X		
Promoting geosynthetics through training and workshops								X		
promoting geosynthetics usage through the availability of manuals on proper methods for construction								X		
promoting geosynthetics usage through the development of quality control measures for geosynthetics usage								X		
availability of design manuals for geosynthetics design									X	
increase geosynthetics education and exposure for prospective and practising civil engineers								X		
Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons								X		
Other measures to enhance the use of geosynthetics:										

APPENDIX 3: Delphi round 2 and questionnaire instructions

Attached is the response computed group median for each of the measures to enhance the use of geosynthetics in Ghana from round one of the Delphi survey. You are at liberty to either accept the group response as computed, indicate a new response, or maintain your own response in round one. In case your response differs from the group median please provide a reason/comment. Also, new measures identified from round one of the surveys have also been included for your response: these are indicated in a yellow shade.

Q1. Base on your knowledge and experience please indicate the extent to which the underlisted measures will be of impact in enhancing the use of geosynthetics in Ghana by placing “X” in the boxes provided against each measure using a 10-point scale?

Measures to enhance the use of geosynthetics	From no impact to very high impact										
The use of geosynthetics could be enhanced through :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Group Median**
Readily availability of geosynthetic products in the market											9

Measures to enhance the use of geosynthetics	From no impact to very high impact										
The use of geosynthetics could be enhanced through :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Group Median**
Provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning											8
Educating clients on geosynthetics options for meeting their infrastructure needs											8
Educating construction practitioners on geosynthetics options for meeting their infrastructure needs											9
development of country-specific standards for geosynthetics application											8
investment in geosynthetic-related research											8
Promoting geosynthetics through training and workshops											8
promoting geosynthetics usage through the availability of manuals on proper methods for construction											8
promoting geosynthetics usage through the development of quality control measures for geosynthetics usage											8
availability of design manuals for geosynthetics design											9
increase geosynthetics education and exposure for prospective and practising civil engineers											8
Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons											8
setting up a geosynthetic think tank to advocate for the use of geosynthetics											8

Measures to enhance the use of geosynthetics	From no impact to very high impact										
The use of geosynthetics could be enhanced through :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Group Median**
promoting geosynthetics usage in the manifestos of political parties											8

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