MEASURES TO ENHANCE THE USE OF GEOSYNTHETICS FOR CIVIL INFRASTRUCTURE PROJECTS: AN EXAMPLE FROM GHANA

ABSTRACT

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative influence of each measure. In all fourteen measures were identified to be of impact in enhancing the use of geosynthetics for civil infrastructure projects in Ghana. Out of the fourteen measures two were unique to this study in Ghana namely: setting up of a geosynthetic think tank to advocate for the use of geosynthetics and promoting geosynthetics usage in the manifestos of political parties. Relatively, setting up of a geosynthetic think tank to advocate for the use of geosynthetics recorded RII score of 0.97 and ranked 1st whiles increase geosynthetics education and exposure for prospective and practicing civil engineers with RII score of 0.79 ranked 14th. This study was 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 hither to was not in existence.

Keywords: Building, Civil Infrastructure, Geosynthetics, Ghana, and Technology.

INTRODUCTION

Geosynthetics are polymeric materials used to enhance, improve or stabilize a soil, rock, earth or any geotechnical substance as an integral part of civil infrastructure (ASTM, 1994; Ziegler, 2017; Khan & Singh, 2020). They come in the form of strips, straps, sheets, or three-dimensional structures (Oginni & Dada, 2021; The Constructor, 2022). The root of the use of geosynthetics could be traced to the days of the Pharaohs in ancient Egypt when natural geosynthetics made of jutes, wood, and raffias, among others, were used to improve soil conditions in road works (Agrawal, 2011).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 (Alao, 2011; Rawal, et al., 2016).

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 (Ziegler, 2017). For example, for landfill sealing systems with intelligent geosynthetics (eg intelligent geomembranes), the electro-resistive sensors in the intelligent geomembrane detect possible leakage in the vicinity of the geomembrane (Ziegler, 2017). Also, another group of intelligent geosynthetics integrate polymer optical fibres (POF) into the geosynthetics (Ziegler, 2017).For instance, for a dam structure that integrates intelligent geosynthetics, the geosynthetic enables continuous observation of the deformations so that a beginning collapse warning is given in advance and people can be timely evacuated for to a safer place (Ziegler, 2017).

Geosynthetics have a wide range of applications in hydraulics engineering, environmental engineering, construction engineering, transportation engineering, 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 (Macharia, 2019; The Constructor, 2022) with road projects being the civil infrastructure projects with most application of geosynthetics (Macharia, 2019). There are nine main types of geosynthetics namely geotextiles, geonets, geogrids, geomembranes, geosynthetic clay liners, geofoams, geopipes, geocomposites, and geocells (Qamhia & Tutumluer, 202 1;The Constructor, 2022), with geotextiles and geomembranes being the most applied geosynthetics (Ministry of Textiles, 2013; Adewumi, 2018; followed by geogrids (Adewumi, 2018).

The primary functions of geosynthetics include reinforcement, stabilization, erosion control, filtration, fill material, containment, drainage, separation, and protection (Ministry of Textile, 2013; Khan & Singh, 2020; Oginni & Dada, 2021).The use of geosynthetics reduces the use of natural materials (Raja, 2011; Pinho-Lopes, 2018).It contributes to the delivery of low-cost and time-efficient projects (Raja, 2011; Elragi, 2000; Khan & Singh, 2020; Wu, et al., 2020),improves slope stability, and generally modify the conditions of the soil (GMA, 2002; Bayraktar, 2020; Oginni & Dada, 2021). Furthermore, the use of geosynthetics contributes to carbon reduction (Raja,2011). In the United Kingdom (UK), WRAP (Waste and Resources Action Progamme), 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 (WRAP, 2010; Raja, 2011). 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 (WRAP, 2010; Raja, 2011).

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 (Oginni and Dada, 2021). 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 give an account of the measures to enhance the use of geosynthetics for civil infrastructure projects. Hence, the relevance of this current study as it presents 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 (Somiah et al., 2022), the extent of application of geosynthetics to civil infrastructure projects (Somiah et al., 2022), 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 design approach in studying geosynthetics (see Raja, 2011, Macharia, 2019; Khan & Singh, 2020, Somiah et al., 2022). Whereas none of the studies 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 (Tengan & Aigbavboa, 2018; Somiah et al., 2020). 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 influence 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 (Somiah et al, 2022).

MEASURES TO ENHANCE THE USE OF GEOSYNTHETICS FOR CIVIL INFRASTRUCTURE PROJECTS: A SURVE OF PREVIOUS STUDIES

Regarding the measures to enhance the use of geosynthetics for civil infrastructure projects some few country-specific studies have been advanced over the years. According to (2011) and Ministry of Textile (2013) product availability, content provision in existing curriclumn are critical in enhancing the level of use of geosynthetics. The United States Environmental Protection Agency (2001) metioned the provision of laboratoreis for testing of geosynthetics will enhance its use as designers will be certain of the design strength of their specifications. Furthermore, the Ministry of Textile (2013) and Raja (2011) informed that educating clients and construction industry practitioners on geosynthetics increases awareness and translates into enhancing the use of geosynthetics.Again, development of country-specific standards,investment in geosynthetic related research, inclusion geosynthetics in standard form of contracts, and publishing standard schedule of rates for geosynthetics culminate into promoting the use of geosynthetics(Ministry of Textile, 2013).

According to Raja (2011) promotional literature, training and workshops, conferences presentations on geosynthetics, geosynthetics exhibitions/events, corporate entertainment, social media advertisement, setting up of geosynthetic technical committees to promote usage are all measures that enhance the use of geosynthetics. Likewise, Palmeira et al. (2021) asserted that publicizing the comparative advantages geosynthetics have over traditional alternatives create awareness and enhance 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 (GSI, 2015).Raja 2011 affirmed this view by advocating for the institution of educating the educator programme in the UK to enhance the use of geosynthetics. Again, institution of training programmes for academics is essential in enhancing the use of geosynthetics (Kawalec 2014; Boyle et al., 2015).

In a study in USA, measures to enhance the use of geosynthetics included establishment of proper mechanisms for geosynthetics applications, and availability of manual on proper methods for construction and quality control measures for geosynthetics usage (Qamhia & Tutumluer, 2021). Development of quality assurance tests and procedures for geosynthetics usage, availability of design manuals and training courses, increase geosynthetic education and exposure for prospective and practicing civil engineers, inclusion of geosynthetics in every civil engineering undergraduate programme, and development of regulatory and national code bodies to develop generic specifications (Boyle et al., 2015).

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, readily accessibility of geosynthetic products in the market, provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning, educating clients on geosynthetics option to meeting their infrastructure needs, educating construction practitioners on geosynthetics option to meeting their infrastructure needs, development of country-specific standards for geosynthetics application, investment in geosynthetic related research, publicizing the comparative advantages geosynthetics have over traditional alternatives, promoting geosynthetics through trainings and workshops, setting up of geosynthetic technical committees to promote usage, providing training and refresher courses in geosynthetics to training providers , development of quality control measures for geosynthetics usage, promoting geosynthetics usage through the availability of manual on proper methods for construction, promoting geosynthetics usage through the development of quality control measures for geosynthetics usage, existence of quality assurance tests for geosynthetics applications, availability of design manuals for geosynthetics design, increase geosynthetics education and exposure for prospective and practicing civil engineers, inclusion of geosynthetics in every civil engineering undergraduate programme, 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.

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 .The Delphi is applicable for both qualitative and quantitative research (Tengan & Aigbavboa, 2018; Somiah et al., 2020). It involves the use of a structured questionnaire in soliciting views from expert panellists through rounds of questionnaire surveys (Tengan & Aigbavboa, 2018; Somiah et al., 2020). This study employed the Delphi technique and adapted the detailed Delphi process outlined by Aigbavboa (2014) (see Figure 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 studies. The second step was the selection of experts to constitute the panel for the Delphi study. The key stakeholders within the geosynthetics chain comprised the academics, researchers, manufacturers, suppliers, designers, contractors (Boyle et al., 2015), and government (Ministry of Textiles, 2013). 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 Aigbavboa, 2014; Tilakasiri, 2015). Hence, they were drawn from industry and academia. According to Aigbavboa (2014) critical to the selection of experts is the theoretical and practical knowledge of the experts. Hence, the check list 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 strong 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 fifteen 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 (Tengan and Aigbavboa, 2018; Somiah et al., 2020). Thus, based on recommendations from previous studies that employed the Delphi technique the 15 panellists for this current study was deemed adequate.

According to Tengan and Aigbavboa (2018) 10 to 15 panellists are sufficient for a Delphi study. Afterward, the instructions and the questionnaires for round one of the Delphi survey was sent to the experts (see Appendices 2 and 3). Fifteen experts responded to both round one and two of the survey.

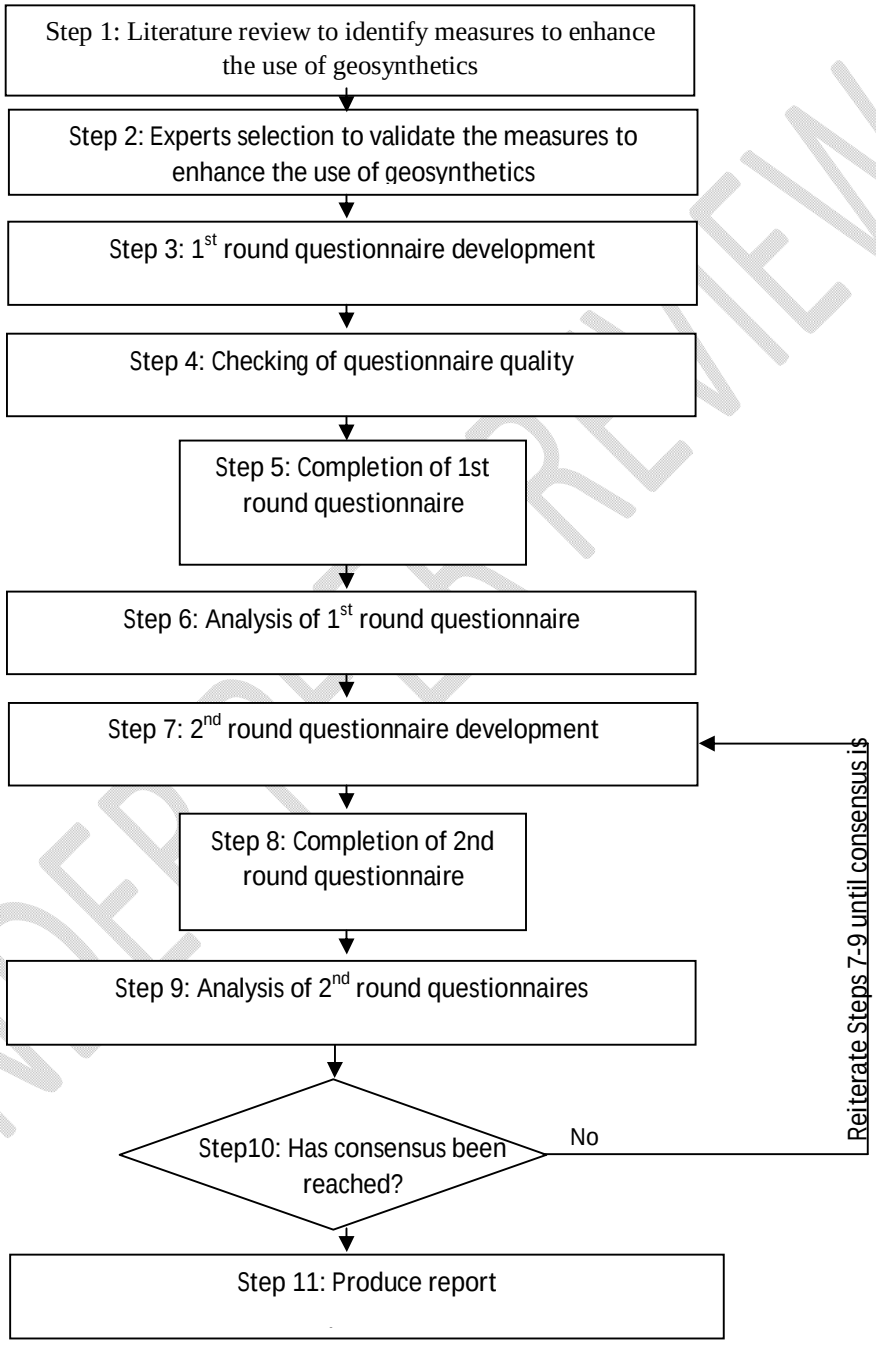

Figure 1: Diagram of the Delphi process
Source: Adapted from Aigbavboa (2014)

Table 1. Respondents' demographic characteristics

Respondents' demographics characteristics	Frequency(n=15)	Percentage (%)
Place of work		
Academic institutions	6	
Research institutions	2	
Suppliers	2	
Consultants	2	
Contractors	3	
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
6-10 years	4	26.7
11-15 years	6	40.0
16-20 years	2	13.3
Over 20 years	3	20
Total	**15**	**100**

Relating the demographic characteristics of the experts with the checklist for selecting experts (see appendix 1) revealed that the minimum obtained mark for 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 obtained 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 were 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 have 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. Similar approach was used by Raskin (1994) and even in quite recent studies (see Aigbavboa, 2014; Adnan et al., 2018; Tengan and Aigbavboa, 2018). 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$\geq 1{,}1 \leq 2$; and
3. Weak consensus - median ≤ 6.99, relative impact index ≤ 0.59 and IQD$\geq 2{,}1 \leq 3$.

This was based on a 10-point impact scale where 1 and 2 represent no impact; 3 and 4 represent low impact; 5 and 6 represent medium impact; 7 and 8 represent high impact; 9 and 10 represent very high impact. In addressing the challenge of validity, reliability, and generalization of results associated with qualitative studies (Bryman, 2001; Tengan and Aigbavboa (2018) asserted that validity, reliability and generalization of Delphi findings is anchored on the rigorousness of the data collection process (Tengan and Aigbavboa, 2018). In view of this, a rigorous methodological process was adapted for the study (see Figure 1). Also, internal validity was ensured through constant communication with the experts on individual basis and offering the experts the opportunity to freely maintain or effect changes to their response and giving reasons for the latter. Structured questionnaire was used in soliciting data from the panel of experts (see Aigbavboa, 2014; Ameyaw et al., 2016). 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 ethical considerations of a Delphi study (Aigbavboa, 2014; Ameyaw et al., 2016; Tengan & Aigbavboa, 2018).

RESULTS

Delphi round one results

Round one of the Delphi survey was to validates, 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. In all, twelve 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 suggested by the panellists to be of impact in enhancing the use of geosynthetics in Ghana. The two were setting *up of 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 fourteen (14) measures were identified to be of impact in enhancing the use of geosynthetics in Ghana. Out of the fourteen measures, three (3) recorded very high impact (VHI: 9.00-10.00) whiles the remaining eleven (11) had high impact on enhancing the use of geosynthetics in Ghana. The fourteen measures formed the basis of the questionnaire for the round two of the Delphi survey.

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	Median	Interquartile deviation (IQD)
	The use of geosynthetics could be enhanced through:		
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 option to meeting their infrastructure needs	8	0.0
4	educating construction practitioners on geosynthetics option to meeting their infrastructure needs	9	0.0
5	development of country-specific standards for geosynthetics application	8	0.0
6	investment in geosynthetic related research	8	0.0
7	promoting geosynthetics through trainings and workshops	8	0.5

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	Median	Interquartile deviation (IQD)
	The use of geosynthetics could be enhanced through		
8	promoting geosynthetics usage through the availability of manual on proper methods for construction	8	0.0
9	promoting geosynthetics usage through the development of quality control measures for geosynthetics usage	8	0.0
10	availability of design manuals for geosynthetics design	9	0.0
11	increase geosynthetics education and exposure for prospective and practicing civil engineers	8	0.0
12	Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons	8	0.0
13	setting up of a geosynthetic think tank to advocate for the use of geosynthetics	8	1
14	promoting geosynthetics usage in the manifestos of political parties	8	1

Delphi round two results

A total of fourteen measures, with their corresponding medians,were presented to the experts' 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. Out of the fourteen measures, three (3) recorded very high impact (VHI: 9.00-10.00) whiles the remaining eleven (11) had high impact on enhancing the use of geosynthetics in Ghana. Thus, none of the expert panellists changed the stance. As a result, consensus was reached in the view of the expert panellists. Therefore, the Delphi survey ended after round two.

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** The use of geosynthetics could be enhanced through	**Median**	**Interquartile deviation (IQD)**	**Standard deviation**	**Relative impact index**	**Relative impact ranking**
1	readily availability of geosynthetic products in the market	9	0.0	0.00	0.91	4th
2	provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning	8	1.0	0.56	0.89	6th
3	educating clients on geosynthetics option to meeting their infrastructure needs	8	0.0	0.47	0.87	11th
4	educating construction practitioners on geosynthetics option to meeting their infrastructure needs	9	0.0	0.23	0.88	9th
5	development of country-specific standards for geosynthetics application	8	0.0	0.31	0.88	9th
6	investment in geosynthetic related research	8	0.0	0.00	0.90	5th
7	promoting geosynthetics through trainings and workshops	8	0.5	0.00	0.89	6th

SN	**Measures to enhance the use of geosynthetics** The use of geosynthetics could be enhanced through :	**Median**	**Interquartile deviation (IQD)**	**Standard deviation**	**Relative impact index**	**Relative impact ranking**
8	promoting geosynthetics usage through the availability of manual on proper	8	0.0	0.00	0.96	2nd

	methods for construction					
9	promoting geosynthetics usage through the development of quality control measures for geosynthetics usage	8	0.0	0.00	0.85	12th
10	availability of design manuals for geosynthetics design	9	0.0	0.89	0.80	13th
11	increase geosynthetics education and exposure for prospective and practicing civil engineers	8	0.0	0.00	0.79	14th
12	Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons	8	0.0	0.00	0.92	3rd
13	setting up of a geosynthetic think tank to advocate for the use of geosynthetics	8	1	0.55	0.97	1st
14	promoting geosynthetics usage in the manifestos of political parties	8	1	0.70	0.89	6th

Discussions

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative influence of each measure. Fourteen measures were identified to be of impact in enhancing the use of geosynthetics in Ghana. Out of the fourteen (14) measures, three (3) measures recorded very high impact with median score range (VHI: 9.00-10.00). These measures were, readily availability of geosynthetic products in the market, availability of design manuals for geosynthetics design and educating construction practitioners on geosynthetics option to meeting their infrastructure needs. The remaining eleven recorded high impact with median score range (HI: 7.00-8.99). Moreso, two of the measures were unique to this study in Ghana. They were setting up of 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, setting up of a geosynthetic think tank to advocate for the use of geosynthetics obtained RII score of 0.97 and ranked 1st.This measure was unique to this study in Ghana. Promoting geosynthetics usage through the availability of manual on proper methods for construction with RII score of 0.96 ranked 2nd. According to Qamhia and Tutumluer (2021) availability of manual on proper methods for construction is essential due to the lack of manuals to aid construction using geosynthetics. Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of geosynthetics lessons with RII score of 0.92 emerged 3rd. This supports the assertion by Kawalec (2014) and Boyle et al. (2015) 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 GSI (2015) advocated for the institution of a programme to educate lecturers and facilitators who were found to be incapacitated to offer training in geosynthetics engineering.

Readily availability of geosynthetic products in the market with RII score of 0.91 ranked 4th.This was found an essential measure in enhancing the use of geosynthetics (Alao, 2011; Ministry of Textiles, 2013).Investment in geosynthetic related research obtained RII score of 0.90 and ranked 5th .This was consistent with the view of the Ministry of Textile (2013) that investment in geosynthetic related research is a sure measure for promoting the use of geosynthetics. Provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning with RII value of 0.89 ranked 6th . This was consistent with the argument by Alao (2011) and Ministry of Textiles (2013) 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 6th was promoting geosynthetics through trainings and workshops which recorded RII score of 0.89. According to Raja (2011) promoting geosynthetics through trainings and workshops is an essential measure to enhance the use of geosynthetics. Palmeira et al. (2021) further suggested that through workshop and other media, emphasis should also be laid on the publicizing the comparative advantages geosynthetics have over traditional alternatives . Moreso, promoting geosynthetics usage in the manifestos of political parties with RII score of 0.89 ranked 6th. This measure was unique to this study in Ghana only as it was not part of the measures identitifeid through the literature review.

Educating construction practitioners on geosynthetics option to meeting their infrastructure needs with RII score of 0.88 ranked 9th. This was consistent with the earlier findings by Raja (2011) and Ministry of Textile (2013) that the use of geosynthetics could be enhanced by educating construction practitioners on geosynthetics option to meeting their infrastructure needs. Development of country-specific standards for geosynthetics applications with RII score of 0.88 also ranked 9th. According to Ministry of Textile, (2013) the factors that affect the use of geosynthetics are country-specific and thus require the development of country-apecific standards for geosynthetics applications. Educating clients on geosynthetics option to meeting their infrastructure needs obtained RII score of 0.87 and ranked 11th . This supports the view of Raja (2011) and Ministry of Textile (2013) that educating clients on geosynthetics option to meeting their infrastructure needs is an essential measure to enhancing the use of geosynthetics. Promoting geosynthetics usage through the development of quality control measures for geosynthetics usage with RII score of 0.85 ranked 12th. According to Qamhia and Tutumluer (2021) promoting geosynthetics usage through the development of quality control measures for geosynthetics usage is essential measure to enhance the use of geosynthetics.Availability of design manuals for geosynthetics design with RII of 0.80 ranked 13th. availability of design manuals for geosynthetics design was found by Boyle et al. (2015) t be essential measure to enhance the use of geosynthetics. Increase geosynthetics education and exposure for prospective and practicing civil engineers with RII of 0.79 ranked 14th. This affirms the argument by Boyle et al. (2015) that the use of geosynthetics coud be enhanced through increase in geosynthetics education and exposure for prospective and practicing civil engineers.

CONCLUSIONS

This study sought to establish measures to enhance the use of geosynthetics for civil infrastructure projects in Ghana and determine the relative influence of each measure. In all fourteen measures were identified to be of impact in enhancing the use of geosynthetics for civil infrastructure projects in Ghana. Out of the fourteen measures two were unique to this study in

Ghana namely: setting up of a geosynthetic think tank to advocate for the use of geosynthetics and promoting geosynthetics usage in the manifestos of political parties. Relatively, setting up of a geosynthetic think tank to advocate for the use of geosynthetics recorded RII score of 0.97 and ranked 1st whiles increase geosynthetics education and exposure for prospective and practicing civil engineers with RII score 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 hither to was not in existence.

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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

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? 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

Q2. 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								X		

of higher learning										
Educating clients on geosynthetics option to meeting their infrastructure needs								X		
Educating construction practitioners on geosynthetics option to meeting their infrastructure needs									X	
development of country-specific standards for geosynthetics application								X		
investment in geosynthetic related research								X		
Promoting geosynthetics through trainings and workshops								X		
promoting geosynthetics usage through the availability of manual 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 practicing 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
Provision of geosynthetics content in existing curricula in civil and allied programmes in institutions of higher learning											8
Educating clients on geosynthetics option to meeting their infrastructure needs											8
Educating construction practitioners on geosynthetics option to meeting their infrastructure needs											9
development of country-specific standards for geosynthetics application											8
investment in geosynthetic related research											8
Promoting geosynthetics through trainings and workshops											8
promoting geosynthetics usage through the availability of manual 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 practicing civil engineers											8
Institution of training programmes for academics in geosynthetics to enhance knowledge and delivery of											8

geosynthetics lessons											
setting up of a geosynthetic think tank to advocate for the use of geosynthetics											8
promoting geosynthetics usage in the manifestos of political parties											8