African Journal of Applied Research
Vol. 4, No. 2 (2018), pp. 203-215
http://www.ajaronline.com
http://doi.org/10.26437/ajar.04.02.2018.18

DILEMMA OF SUSTAINABLE ROOF FORMS IN WARM-HUMID CLIMATIC ZONES: A SURVEY OF PARAPET ROOFS IN KUMASI, GHANA

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ABSTRACT
Parapet roof designs are not uncommon within the Kumasi Metropolis. This roof typology dates back to the 1970s where buildings were design with the aim of hiding the roofing materials with facades of parapet walls. There is an apparent dilemma with this roof typology and the past decade has, however, witnessed re-roofing of many such buildings. This paper is aimed at finding out the apparent dilemma of this roof form with regards to the rampant re-roofing. Survey methods, questionnaire, interview and photography were used for data collection and analysis. It was revealed that High cost of maintenance due to rain water leakages account for a total majority of reasons for re-roofed buildings, followed by subjective norm and perceived outmoded architectural style.

***Key words**: Parapet walls, Roof forms, Re-roof, Leakage, Sustainable roofs*

INTRODUCTION
Roofs are regarded as critical part of the building envelope which prevents rain water from entering the interior spaces. Roofs are usually the upper covering which serve as caps to protect the structures underneath (Omotehinshe et al., 2015). Myanmar and Ferretti, (2009) considers roof as an important component of shelter for protection against harsh weather conditions. The term "roof" is defined as the covering on top of a building, the structure forming the upper waterproof finish, serving to protect against rain, snow, sunlight, wind, and extremes of temperature. Roofs can be constructed in a wide variety of forms (flat, pitched, vaulted, domed, or in combinations, depending upon technical, economic, or aesthetic considerations) (Fiumi, 2012). Kumasi, the second largest city in Ghana and the capital of the Ashanti region has buildings with different roof forms/typologies as there is much importance and respect placed on house ownership such that it is worth asking of one's house and not his wealth, caption in the local language as "*yɛ bisa onipa no fie, na yɛ mmisa ne sika"* (Oppong and Solomo-Ayeh, 2014). The roof typologies include concrete flat roofs, roofs with parapet walls round a concrete rain gutter, pitch roof with gable ends and hipped roofs. Construction of the roof with parapet walls round a concrete rain gutter, known as "*bohyɛmu*" in local parlance (Afram, 2008), dates back to the 1970's where there was a movement from the existing pitch roofs in an attempt to conceal the roof members. A roof, irrespective of typology or form, is expected to keep interior spaces

ISSN: 2408-7920

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http://doi.org/10.26437/ajar.04.02.2018.18

dry and protect occupants against harsh weather conditions (Lawson, 2012). Furthermore, some functions of roofs are to provide shade to external walls and withstand superimposed load such as wind and rain. Roofs should be durable, aesthetically pleasing (Afram, 2008) and sustainable. Parapet roofs has no exception to this expectation. The architecture of Kumasi is going through significant changes in traditional building forms (Twumasi-Ampofo and Oppong, 2016) and re-roofing of parapet roofs has become a common phenomenon . There is an apparent dilemma with this roof typology such that while many occupants are re-roofing over parapet walls, others are busy constructing new buildings with same (parapet roofs).

Parapet Roofs

Parapet roofs are roofs with walls which are built as external walls or fascia along edges to concrete roof gutters. This type of roof usually has roofing sheets made of corrugated aluzinc or aluminium with an angle not more than 10^{o}. This angle therefore hides the roof leaving only the parapet walls which form simple and clear façades (Afram, 2008). Roofs with parapet walls seem to follow the Baroque style of architecture where hidden roofs, characterised by balustrades with cornices (parapet) crowning an entire building, was the order-of-the-day in the late 16^{th} Century (Bellori, 1976) and Modern style of architecture. Some historians regard modernism as a matter of taste, a reaction against eclecticism and the lavish stylistic excesses of Victorian and Edwardian architecture (Boyer, 1983). Some common characteristics of modern architecture include simplicity and clarity of forms and elimination of "unnecessary detail" and materials (building elements) at 90 degrees to each other (Jagape, 2014). “From the aesthetic perspective, it may be merely a client’s own idiosyncrasy or an attempt to hide an inexpensive and not too appealing roof covering from public view. The latter reason is what prevailed in Ghana in the early 1970s, especially in the city of Kumasi” (Afram, 2008). The former, for this study, cannot be ruled out considering an assertion by Bhatia, (1994) as sited in Oppong and Solomo-Ayeh, (2014) that a house, however perverted, is a display of personal taste. Apart from hiding the roofing sheets, the concrete roof gutter collects rain water which is directed downwards through spouts. A study about the effects of parapet walls on roof pressures by Pruitt (2001), however, concluded that parapet walls built around roofs help to reduce wind pressure and turbulence over roofs and edges of roofs respectively. Meanwhile, Davenport and Surry (1974) had suggested that a low parapet (less than 600mm) was worse than having none at all.

Sustainable Roof

Sustainable roof is a roof which is designed to allow repair or renovation and re-use as well as recycling at the end of its life with economic performance as a major factor among other factors such as ease of the roof structure installation, life cycle maintenance of the roof, availability of material, availability of personnel and technological know-how of the personnel at the local level (Brian et al. 2014). The essence of sustainability is long-term service life and it is recommended that all roof systems looking to achieve sustainability be designed for a 30-year service life (Hutchinson, 2009). The roof’s contribution to environmental issues ranges between 2% and 12% of the total building (Harrison et al., 2009). It is therefore, worth noting that environmental issues, such as, climate change, fossil fuel depletion, embodied energy, minerals extraction and waste disposal, need to be taken into account when specifying roofs and roofing in sustainable

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new construction, and with refurbishment of older buildings as has been the case of some buildings in Kumasi.

This paper therefore seeks to ascertain this dilemma as to the reasons for widespread re-roofing of old parapets while new roofs with parapets are still being constructed and recommend sustainable ways of keeping problem free roofs.

Dilemmas in Sustainable Development

A review of the literature indicates that there exists copious studies in the sphere of sustainable development (Bonenberg, 2018; Ubarte and Kaplinski, 2016; Kaklauskas, 2015;), but few in the area of dilemmas in sustainable architecture development. Bonenberg and Kaplinski, (2018) presents a review of dilemmas in sustainable development with emphasis on paradigms such as designing from traditional to integrated, the place and role of the architect in the implementation of the multidimensional processes of sustainable design. Fuller et al. (2008) explores the ethical dilemma faced by architects in the residential sector when confronted by a client who wants a house that is clearly unsustainable. The dilemma theory as explained in the works of Hampden-Turner and Fons Trompenaars states that a dilemma is a choice between two options, both of which are attractive but appear to be mutually exclusive (Ramsey, 2018). There seem to a dilemma within the society with regards to the choice and design of roof forms. This is a form of social dilemma which indicates a situation in which a win–win solution cannot be realized due to an incentive structure that induces rational actors not to act in a mutually beneficial way even though it would be in their common interest to do so (Pies et al., 2009; Valentinov and Chatalova 2014).

RESEARCH METHODOLOGY

The study combines qualitative and quantitative methods with the use of questionnaire, semi-structured interview and photographs of identified buildings to obtain data. Questionnaire and interview were used to obtain empirical data from heads of the households as well as building owners in randomly sampled buildings. The survey inquired as to completion date of the building, reasons for choosing parapet roofs, why the re-roof etc. Interview was used to explore occupants' experiences and perspectives (Corbin and Strauss, 2008) in buildings within the Kumasi Metropolis. These buildings are located in different suburbs of the Kumasi metropolitan area (Figure 1) namely Ahodwo, Daban, Atasemanso, Nyiaeso, Dakwodwom, Adum, Asafo, Amakom, Santasi, Patasi, Asokwa, Adukrom, Aboabo, Dichemso, KNUST and its surrounding towns with year of completion from 1960 to 2017. Three persons together with the authors administered the questionnaire and conducted interviews in addition to taking relevant photographs of one hundred and twenty-six (126) buildings out of which a total of ninety (90) are re-roofed and thirty-six (36) newly constructed parapet roof buildings not re-roofed. Data collection lasted about six weeks with a limitation of not meeting some heads of households and building owners at the initial visits but persistent visits and phone calls helped to obtain relevant data for the study.

ISSN: 2408-7920

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http://doi.org/10.26437/ajar.04.02.2018.18

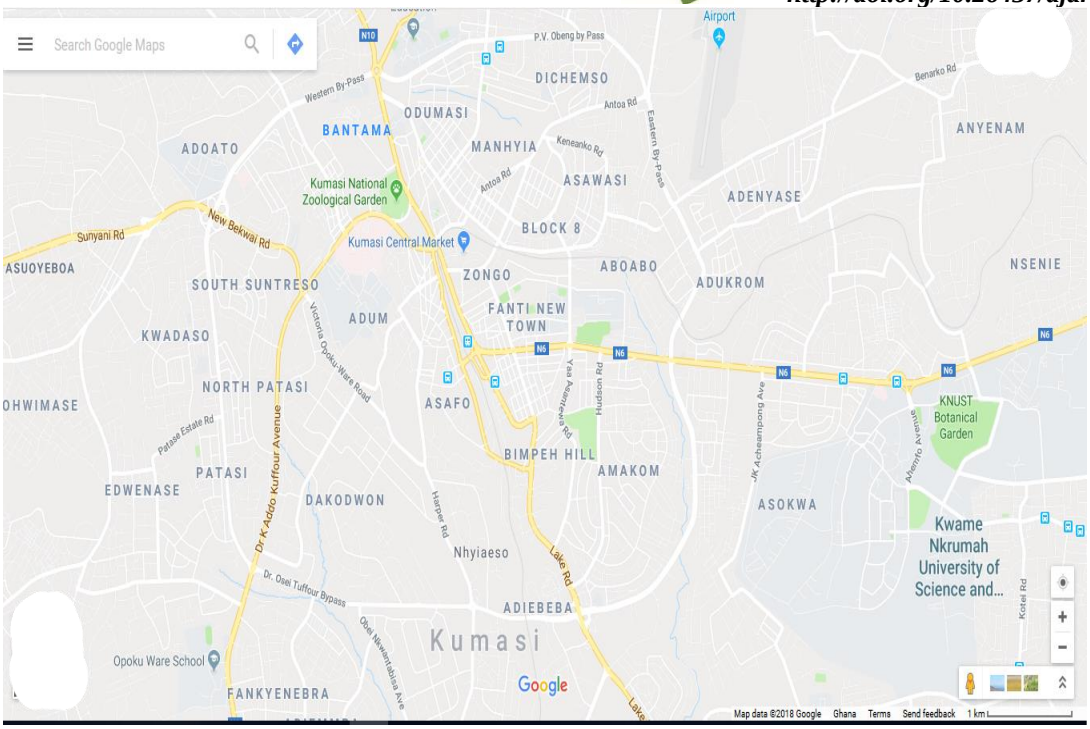

Fig. 1. Layout of Study Area. Source: Google maps, 2018

Characteristics of the study area

Kumasi Metropolis is the capital city of Ashanti Region located between latitude 6.35ºN and 6.40ºS and Longitude 1.30ºW and 1.35ºE and elevated 250 to 300 meters above sea level. It is approximately 270km north of the national capital, Accra. It has a surface area of approximately 214.3 square kilometres which is about 0.9 percent of the region's land area. However, it accommodates about 2,035,064people (36.2%) the region's population (GSS, 2014). About 86% of the active population in Kumasi is economically active with an average number of households per house being 3.4 in 119 communities within ten (10) kilometres radius (KMA, 2014). Kumasi lies within the warm humid climatic zone with average monthly temperature of 18ºC, 260cm rainfall a year and daily humidity levels between 77% and 88% (London, 2018).

DATA ANALYSIS AND DISCUSSION

One hundred and twenty Six (126) buildings were studied showing the dilemma of roof forms with Table 1 indicating the re-roofed parapets and the new concrete parapet roof buildings and the number of floors (stories).

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Table 1: Re-roofed and New Parapets

	Building Type (Story)				Total
	1	2	3	4	
Re-roofed	59	19	8	4	**90**
New Concrete Parapet	8	17	5	5	**36**
Total	**68**	**36**	**13**	**9**	**126**

Source: Field survey, January, 2017

From Table 1, ninety (90) of the buildings studied had been re-roofed with its parapet completely covered with long span aluzinc sheets while thirty-six (36) of the buildings have new roofs with concrete parapet indicating clearly the dilemma of roof forms as shown in Figures 2 and 3. More than 50% (64) of the respondents living in re-roofed buildings inherited from their parents.

Fig. 2. Green re-roofed parapet building with a newly constructed concrete parapet roof next to each other off Lesley Opoku-Ware Drive. Source: (inset) Authors, 2016; Google maps, 2018.

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Fig. 3. A parapet roof completed in 1976 being re-roofed and a new concrete parapet roof building on the next plot of land along Victoria Opoku-Ware Road. Source: (inset) Authors, 2016; Google maps, 2018.

Out of the 90 re-roofed buildings, more than 50% (59) are single story buildings, 19 of them two-story buildings, 8 of them have three floors while 4 of them are four-story buildings. Meanwhile, a total of thirty-six (36) of the buildings studied are newly constructed with concrete parapet roofs. Majority (17) of the new concrete parapet roof building are two-story with 8 being single story buildings while 5 each being three and four stories respectively.

Purpose for Buildings

The buildings studied were for various purposes including civic, commercial, education and residential. This is evident in Table 2 with majority (86) being used for residential purposes, followed by commercial buildings (20), 13 buildings for educational purposes while buildings used for civic purposes are the least with 7 in number. Furthermore, these buildings with various purposes have varying floor levels with a total of 68 having one floor, 36 having two floors, 13 three floors and the least (9) having the highest (4) floor levels.

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Table 2: Purpose for Buildings

Purpose					
Stories (Floors)	**Residential**	**Commercial**	**Civic**	**Educational**	**Total**
1	61	3	2	2	**68**
2	22	8	1	5	**36**
3	3	5	2	3	**13**
4	0	4	2	3	**9**
Total	**86**	**20**	**7**	**13**	**126**

Source: Field survey, January, 2017

From table 2, none of the 86 residential buildings has four floors (stories) and above. More than 50% of these residential buildings (61) are single story, 22 are two stories with three having three stories. Meanwhile, the commercial buildings studied indicate a majority (8) having two stories while the least (3) have one floor with 25% (5) and 20% (4) having three and four stories respectively. Out of the 7 civic buildings studied, two each have one, three and four stories respectively while one have two stories. Three each of the 13 educational buildings studied have three and four stories respectively with majority (5) two floors while the least (2) have single story.

Reasons for Parapet Roof

Reasons given by respondents (Table 3) for old buildings with parapet roofs ("*bohyɛmu*") include economic, aesthetics, roof protection from strong winds among other reasons such as influence by the society i.e. subjective norm either by piers or family members. In an interview some stated that *"it was the type of roof trending at that time so I followed it". Others "simply liked it"* which confirms Boyer, (1983) assertion that it is a matter of taste. Economic reasons has to do with hiding the roof with shallow pitch to reduce the quantity and cost of timber members used as rafters and purlins. Moreover, there is no need to procure "expensive" long span, concrete tiles or clay tile roofing sheets if the roof is hidden. 81 out of 126 respondents claim that the used short span aluzinc roofing sheets because it is relatively cheaper. All these 81 buildings were completed before 2000. Parapet roof's simple clear façades (Afram, 2008) which characterises the modern architectural style as stated by Jagape (2014) seem aesthetically pleasing to a majority 55 respondents. 29 responded that having a roof hidden in a parapet wall protects it from the adverse effect of strong winds while 18 respondents had no clear reason for their choice but were influenced by the society and what was trending during the time.

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Table 3: Reasons for Parapet Roof

Year of completion	Reason				Total
	Economic	Aesthetics	Roof Protection	Other	
Before 1960	2	0	2	0	**4**
1961-1970	3	1	5	0	**9**
1971-1980	12	18	11	6	**47**
1981-1990	2	6	3	1	**12**
1991-2000	0	4	2	3	**9**
2001-2010	3	8	3	2	**16**
2011- 2017	2	18	3	6	**29**
Total	**24**	**55**	**29**	**18**	**126**

Source: Field survey, January, 2017

Table 3 indicates that 72 out of the 126 buildings studied were built before 1990 which falls within Hutchinson's (2004) definition for sustainable roofs with lifespan up to three decades while 54 buildings were completed less than 27 years ago. It is worth noting that the crave for parapet roofs rose to its peak in the 1980s (47), reduced to 9 in the 2000s and rose again up to 29 from 2011 to 2017 (Figure 4).

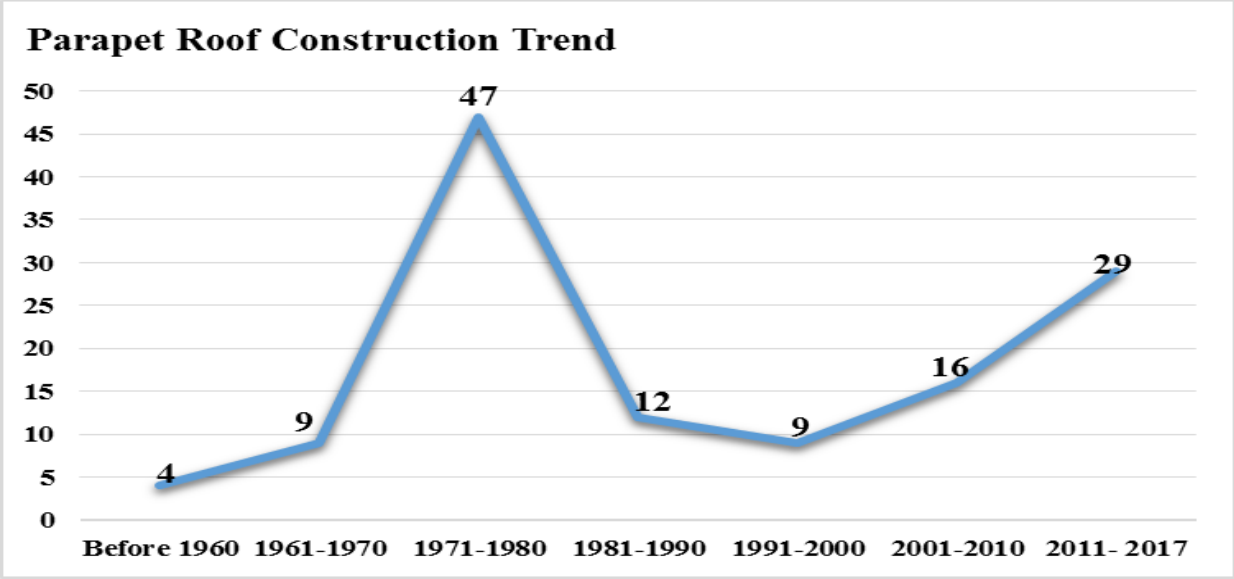

Fig. 4. Parapet roof construction trend. Source: Authors, 2016

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Reasons for Re-roof

The study brings to bare various reasons for re-roofing the existing parapets. 90 out of the 126 parapet roofs studied had been re-roofed with reasons including; leakage of rain water into indoor spaces, high cost of roof maintenance, perceived outmoded architectural style and subjective norm. Roof leakages from defective sheets and concrete rain gutters is a major (41) reason why the parapets are re-roofed. It is clear from Table 4 that most of the re-roofed buildings are more than thirty years old (from 1980) while the buildings from 2001 to date recorded no leakage problems. 21 respondents 90 admitted that it is expensive to maintain parapet roofs and had to cover it up (re-roof) to save cost. High cost of maintenance is caused by regular repair of roofing sheets and concrete rain gutters to prevent rain water leakage. 15 buildings re-roofed due to high cost of maintenance were completed before 1980 with 6 completed within the past four decades. 12 respondents interestingly, perceived that the parapet roofs are old-fashioned and therefore needed to change into a more fashionable designs and roofing sheets i.e. coloured long span aluzinc sheets. A significant 16 respondents re-roofed the parapets due to societal influence (subjective norm). The decision to re-roof in this study is highly influence by family and friends. These buildings were re-roofed simply because a family member or friend has done same.

Table 4: Reasons for re-roof

Year of completion	Reason				Total
	Leakage	High cost of Maintenance	Perceived Outmoded Architectural style	Subjective Norm	
Before 1960	3	1	0	0	**4**
1961-1970	5	2	0	2	**9**
1971-1980	27	12	2	6	**47**
1981-1990	5	3	1	3	**12**
1991-2000	1	0	3	0	**4**
2001-2010	0	2	2	3	**7**
2011- 2017	0	1	4	2	**7**
Total	**41**	**21**	**12**	**16**	**90**

Source: Field survey, January, 2017

Further inquiry as shown on Table 4 indicates that all the buildings completed before 1990 in the study (72) has been re-roofed while 18 re-roofed buildings were completed between 1991 and 2017.

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Reasons for New Parapet Roof

The new parapet roofs for this study are for buildings completed between 1991 and 2017 which has a total of 54 with 18 of them re-roofed. This section however, deals with 36 out of the 54 newly constructed buildings not re-roofed (Figure 5). Parapet roofs (not re-roofed) as shown in table 3.4 indicates an increase trend starting from 5 within 1991-2000, through 9 within 2001-2010, to a majority (22) within 2011 and 2017.

Fig. 5. New Concrete Parapet Roofs. Source: Authors, 2016

Reasons that accounted for having new parapet roofs as given by respondents, include; economic, aesthetics, roof protection among others. In table 5, about 58% (21) of the respondents attributed the reason for parapet as being aesthetically pleasing, about 30% (11) perceived it to act as a protection for the roof while about 12% (4) followed a subjective norm i.e. what has been done by the family and friends. Surprisingly, there was no responds for economic reasons for these 36 buildings.

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Table 5: Reasons for New Parapet Roof

Year of completion	Reason				Total
	Economic	Aesthetics	Roof Protection	Other	
Before 1960	0	0	0	0	**0**
1961-1970	0	0	0	0	**0**
1971-1980	0	0	0	0	**0**
1981-1990	0	0	0	0	**0**
1991-2000	0	3	1	1	**5**
2001-2010	0	5	3	1	**9**
2011- 2017	0	13	7	2	**22**
Total	**0**	**21**	**11**	**4**	**36**

Source: Field survey, January, 2017

CONCLUSION AND RECOMMENDATIONS

The dilemma of roof forms as presented in study seems a long standing one with a continuous rise in new parapet roof construction from the year 2000 to 2017 while old parapets are still being re-roofed. It is worth mentioning that re-roofing over the parapet walls end up changing the Architectural style of the buildings even though it seem to solve occupant's problem of leakages. Although, economic reason is prominent in the decision to construct parapet roofs for old buildings, new buildings constructed with parapet roofs seem not to care about economic reasons. Newly constructed parapet roofs rather place emphasis on aesthetics as the ultimate reason, keeping simple clear façades. While the old parapet roof covering is short span aluzinc sheets, the new parapet roofs are covered with coloured long span aluzinc sheets. High cost of maintenance due to rain water leakages account for a total of about 68% of reasons for re-roofed buildings, followed by subjective norm and perceived outmoded architectural style. If Hutchinson's (2009) recommendation for sustainable roofs is anything to go by, then all the buildings re-roofed apart from the 18 (1991-2017) achieved its 30-year service lifespan. This paper concludes that the rate of re-roofing is higher than the rate at which new parapets are constructed and the roofs with long overhangs (without parapets) seem to perform better than parapet roofs. It could be predicted from the study that more parapet roofs are likely to be re-roofed after 30-year life span.

This paper therefore recommends that, roofs in warm humid climatic zone should be well designed and constructed to prevent leakages and high maintenance cost which has been the

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major causes of re-roofing. Moreover, building owners must be careful not to be carried away by societal influence in their choice for roof form.

Acknowledgement
The authors thankfully acknowledge the services of Sampson Kusi, Fahran Safyan and Lois Yamoah Gyasi during data collection for the study.

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