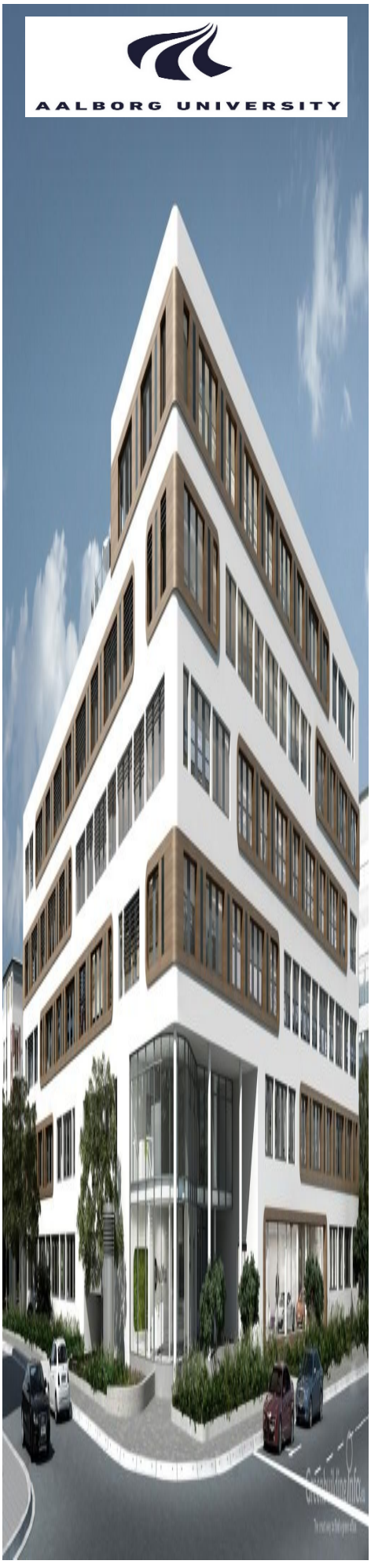

MASTER'S THESIS PROJECT REPORT

GREEN BIM:

ADATATION OF GREEN BUILDING DESIGN CONCEPT WITH BIM INTO A NEW CONSTRUCTION MARKET - GHANA

IN THE AEC/FM INDUSTRY

SUBMITTED BY:

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[*Supervisor: Associate Professor - Kjeld Svidt*]

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Abstract

In the western world, the emergence of BIM technology with Green Building Design concept has revolutionized the Built Environment in recent times. The Green BIM concept is developing very fast and millions of Governmental institutions, Professional Bodies, Construction companies, and Research Institutions are embracing its massive impacts and contribution to construction management and projects delivery for both public and private projects. The efficiency and effectiveness of this technology is not well known in the Ghanaian Construction industry and Africa in General. The question is ***"how to adapt and implement Green BIM concept into the construction market in Ghana?"*** In order to improve its construction management and projects delivery system in the Architecture, Engineering, Construction, and Facility Management Industry in Sub-Saharan Africa.

This Thesis report has been able to ascertain some problems related to Construction management and operational process such as lack of good collaboration between project teams, Lack of analysis on energy usage on building projects, Deficiencies in project scheduling and time management, Non-function maintenance culture on constructed buildings, Ineffective mechanism for costs control, technological deficiencies, Projects delays in construction, etc. The Mixed Method Research (MMR) was used for the collecting, analyzing, evaluating and the interpretation of research data for both questionnaires and interviews.

The Green BIM concept in Scandinavia and United Kingdom were investigated and use as a model. The findings of this project research will provides the platform aimed at exploring the technological benefits, strategic advantage and operational flexibility that Green Building Design concept with BIM technology had created in these countries. Its impact in infrastructure development in Scandinavia countries as well as in the United Kingdom. The solutions and recommendation of this study will address the problems stated in the construction industry in Ghana. This will create an enable environment which in turns will stimulate accelerated development in the construction industry and bring growth in that sector of Ghanaian economy.

Preface

This Master's Thesis Report is written as a compulsory part of 4th Semester (Final) of the MSc. in Management in the Building Industry Program, in the School of Engineering and Science at Aalborg University, Denmark.

This thesis report is an original intellectual property of the researcher (Edwin Afreh Ampratwum), the period of conducting this research work is from 2nd September 2016 -9th January 2017. As an international student, the opportunity to studied Building Information Modeling as course in the 3rd semester and the knowledge I gained on the transformation it's creating in Built Environment enthuses me to search deep for a topic that will be my final dissertation project which will improve the construction sector in Ghana if approved by Head of Studies Board (School of Engineering and Science).

The theme "Green BIM: Adaptation of Green Building Design Concept with BIM into a New Construction market - Ghana" is self-originated. However, is to further broaden the existing literature and the knowledge base on the Green BIM concept from the western world into a new market in the sub-Saharan African country of Ghana? This report is focused on exploring innovational possibilities that Green BIM technology offers in Construction management and project delivery.

More so, the use of this report findings is to build a sound platform for Government to make decision and laws that will enhance the AEC/FM industry operations and day to day problems that the industry face in the Ghanaian Construction sector.

Acknowledgements

This thesis report would have not be possible without the Almighty God grace of good health, wisdom, endurance, knowledge and strength which he has blessed me with throughout my Master's degree education in Aalborg University, Denmark.

Heartfelt gratitude goes to my thesis report supervisor - Associate professor Kjeld Svidt for his awesome guidance, contribution of ideas and knowledge into the research materials and the invaluable time used to read through my working papers. Again, I extend my thankfulness to all professors especially in the MSc in Management in the Building Industry program during my time of studies who were in charge of the various courses. I am really appreciative to your impacts of knowledge and experience shared at the cause of my studies. Additionally, to Danish Government for the platform giving to me as International student to acquire this knowledge and used it as stepping stone to build my professional career for a better tomorrow.

My special gratefulness goes to all the companies that opened their doors for me to interview some of their employees on my research work and also all the respondents who spare me some of their precious time to answer my questionnaires on this thesis report. I cannot forget personalities like;

- Dennis Berner - Rambøll A/S, Aalborg
- Thomas Fæno Mondrup - Denmark Green Building Council, Copenhagen
- Richard Nsiah - Richnash Company Limited, Kumasi - Ghana

Additionally, to all the Authors, which books, scientific papers, journals etc. were source of inspiration and motivation in putting my thoughts together whilst writing this thesis report. Thank you very Much.

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Table of Contents

Contents

TITLE SHEET i

Abstract ii

Preface iii

Acknowledgements iv

Table of Contents v

List of figures viii

List of Abbreviations ix

Thesis Structure Workflow x

Chapter 1: Introduction 1

1.1 Background 1

1.2 Ghana – New Construction Market 3

1.2.1 Political environment 3

1.2.2 Economic environment 4

1.2.3 Trade and Investments 5

1.3 Ghanaian Construction Industry 6

1.4 Construction market opportunities 8

1.5 Motivation for the Research 8

1.6 Objective of the Research 9

1.7 Initial Problem Statement 9

1.7.1 Contractor (A) – Building and Civil Engineering: 10

1.7.2 Contractor (B) – Road Construction: 11

1.8 Research Questions 12

Chapter 2: Research methodology 13

2.1 Introduction 13

2.2 Literature Reviews 14

2.3 Mixed Methods Research (MMR) 15

2.3.1 Data Collections 16
2.4 Analysis and Discussion 16
2.5 Ethical concern for the Research 17
3.6 Limitation of Research work 18
Chapter 3: Literature Reviews 19
3.1 Building Information Modeling (BIM) Technology 19
3.2 Benefits of BIM Technology Implementation 20
3.3 Challenges in BIM Technology Implementation 22
3.4 Green Building Design 23
3.5 Green BIM Concept 24
3.6 Scandinavian Green BIM and United Kingdom Model 26
3.6.1 DENMARK 26
3.6.2 NORWAY 27
3.6.3 FINLAND 28
3.6.4 SWEDEN 29
3.6.5 UNITED KINGDOM (UK) 30
3.7 Green Building Design and BIM in Sub-Saharan Africa. 31
3.8 Summary on Literature Reviews 32
Chapter 4: Green Building Design 34
4.1 History of Green Building Design and Construction 34
4.2 What is Green Building Design? 34
4.3 What constitute to Green Building practices? 35
4.4 Sustainability Development in Denmark 37
4.5 DGNB Certification in Denmark 38
Chapter 5: Building Information Modeling 40
5.1 Overview Building Information Modeling (BIM) 40
5.1.1 BIM numeric labels Dimensions 42
5.1.2 Origin of Building Information Modeling (BIM) 42
5.2 BIM Integrated Information Model 44
5.2 BIM Data Exchange and interoperability 45
5.3 Building Information Modeling (BIM) Stages 46

5.3.1 BIM Stage 1 - "*Object -Based Modeling Synopsis*" 46
5.3.2 BIM Stage 2 - "*model - based collaboration synopsis*" 47
5.3.3 BIM Stage 3 - *"Network - Based Integration synopsis"* 48
Chapter 6: Analysis of Data and Discussion 49
6.1 Background of Respondents 49
6.2 Stakeholders attitude and perception on Green BIM 51
A. Stakeholder attitude and perception towards Green Building 51
B. Stakeholder perception on BIM Technology 52
6.3 Stakeholders Power/Interest Matrix Analysis 54
6.4 Construction Style Analysis 57
6.5 Technology Analysis 61
6.6 Infrastructure of BIM Development Analysis 64
6.7. Main Problem statement 65
Chapter 7: Solutions and Recommendation 66
7.1 Summary of findings on Research Questions: 66
7.1.1Policy Fields 67
7.1.2. Process Fields 68
7.1.3Technology Fields 68
Chapter 8: Implementation 71
8.1Green BIM Implementation in Ghana 71
8.2Pilot implementation plan - Richnash Company Ltd., Ghana 72
Chapter 9: Conclusion 79
Bibliography 81

List of figures

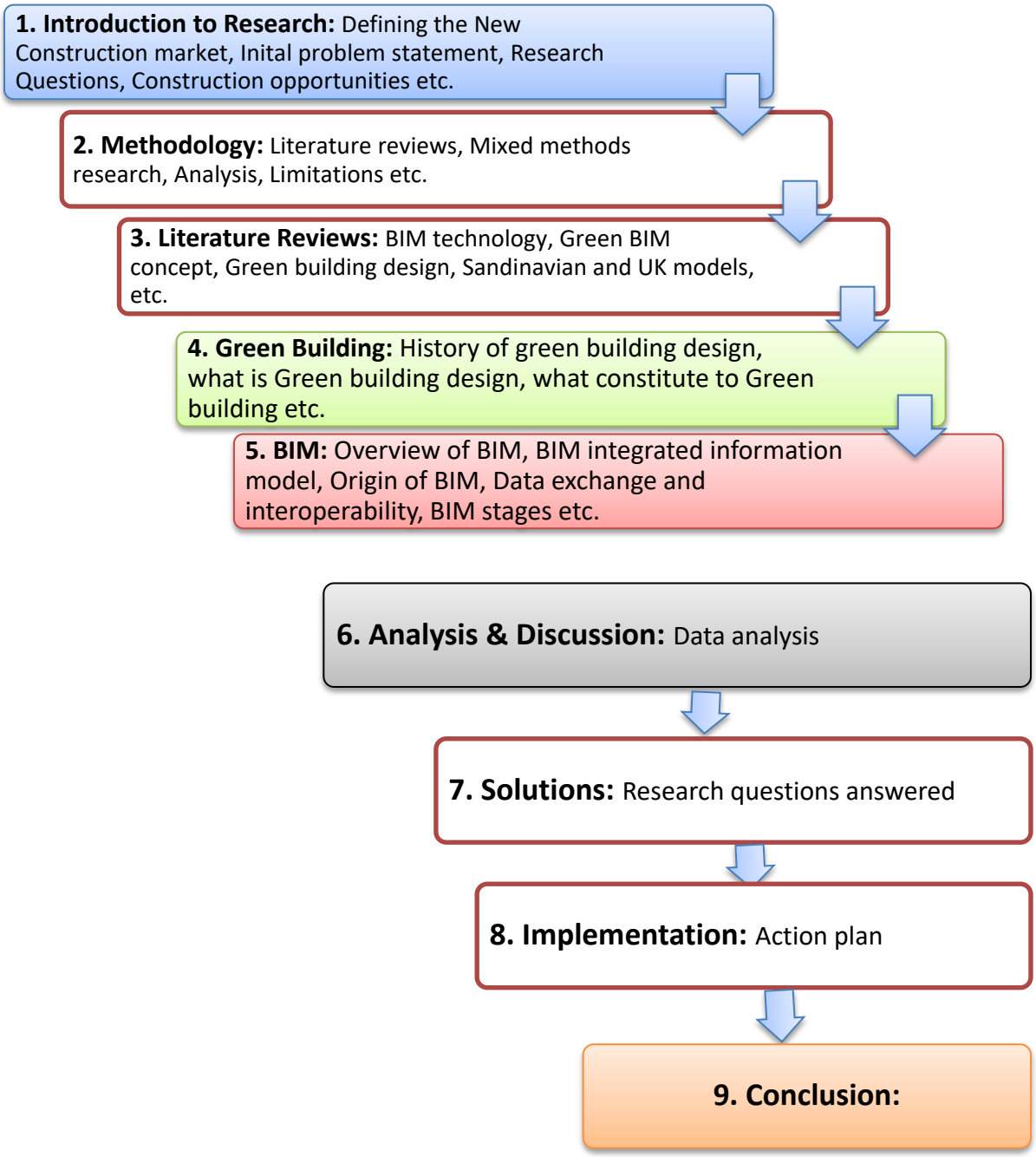
Fig.1: Ghana Population....4
Fig.2: Republic of Ghana Map....4
Fig.3. Growth Rates of Gross Domestic Product at 2006 constant prices....7
Fig.4. Distribution of Gross Domestic Product by Economic Activity....7
Fig.5. Framework for Thesis Report Structure....15
Fig.6. Mixed Methods Research....16
Fig.7 Convergent Parallel Mixed Methods Research....17
Fig.8. Gladsaxe Company House - Copenhagen....27
Fig. 9.KBS Shopping Center - Trondheim....28
Fig.10.Manskun Rasti - Helsinki....29
Fig.11. New Karolinska Solna - Solna....30
Fig.12. New Papworth Hospital - Cambridge....31
Fig.13. illustrated in the DGNB pre-certified buildings per year from 2012 to 2016....37
Fig.14. DGNB building certifications in Denmark and measuring tool for sustainability....38
Fig.15. BIM Functions....40
Fig.16. Development of BIM Definition....42
Fig.17. BIM information model vs traditional....44
Fig.18. Illustrate linear view of BIM maturity....45
Fig.19. Image of single disciplinary model....45
Fig.20. BIM Stage 1 of project phases....46
Fig.21. Illustration of single disciplinary model with 2D BIM integration tool....46
Fig.22. BIM Stage 2 of project phases....46
Fig.23. integrated model with multiple disciplines on single model....47
Fig.24. BIM Stage 3 of project phases....47
Fig.25. Background of survey respondents....48
Fig.26. Illustrate Green Building perceptions of Stakeholders....51
Fig.27. Interest of BIM implementation by stakeholders....52
Fig.28. BIM software use in the construction....53
Fig.29. Stakeholders Power/interest Matrix....54
Fig.30. Illustration of the Macleamy curve, BIM process vs Traditional design....57
Fig.31. Illustration of list of BIM adoption barriers in the Ghanaian construction....59
Fig.32. oversight of some selected CAD software at Rambøll A/S Aalborg....61
Fig.33. Current capacity development in the construction industry in Ghana....62
Fig.34. Three interlocking field of BIM....65
Fig.35. Level of BIM maturity model....70
Fig.36 Focus areas for BIM at Richnash Company Ltd....72
Fig.37 Kotter's Change Model....72

Table 1. Implementation Action plan....73

List of Abbreviations

AEC/FM - Architecture, Engineering, Construction and Facility Management
PPP - Public Private Partnerships
LEED - Leadership in Energy & Environment Design
BREEAM - Building Research Establishment Environmental Assessment Method
CIC - Computer Integrated Construction
BIM - Building Information Modeling
UK - United Kingdom
MMR - Mixed Methods Research
NIBS - National Institute of Building Science
NBIMS - National Building Information Model Standard
ECOWAS - Economic Community of West Africa State
AU - Africa Union
EU - European Union

Thesis Structure Workflow



Chapter 1: Introduction

In 21st century global construction market*, there are always new requirements and regulations on building constructions. The European parliament has even given directives to all its 28 member nations on the use of BIM in 2016 on public funding projects in order to streamline the construction environment. It helps these countries in Scandinavian (Denmark, Sweden Norway, Finland) and United Kingdom to achieve efficiency and effectiveness in their project management system. This chapter explore the Green BIM concept and the successful stories in Scandinavian and United Kingdom after it use. Moreover, highlighting the initial problem statement that ignites the desire to find appropriate solutions to improve organization and operational management system for the new construction market – Ghana. The findings of this research recommendations will be implemented in the Ghanaian construction industry for the Architecture, Engineering, Construction, and Facility Management Industry (AEC/FM Industry).*

1.1 Background

The construction industry has experienced diverse changes lately in terms of technology and environmental consciousness. However, in Ghana, the construction sector is one key pillars for the country's economic growth by way of providing socio-economic infrastructures like residential homes, hospitals, school etc. and again, promoting quality of life in respect to jobs to the Ghanaian citizenry.

In today's world, climate change is of a great concern and the rate of its effect on the environment is alarming worldwide. That is why, designers, companies, and researchers are coming out with modern technologies and energy efficient design structures within the construction industry that will provide green solutions to address some of the global warming challenges. Nevertheless, the idea behind such innovation is to reduce the carbon emissions that occurs as a result of some construction activities in the build environment. (Yusuf Arayici, 2015). The emergence of BIM technology with Green Building Design concept has revolutionized the Built Environment in the western world and it's referred as ***Green BIM***. Therefore, Green BIM is define as, the ability to assess sustainability aspects including near zero carbon in construction, optimizing energy usage, optimizing the environmental performance, efficiency in managing waste, improvement on indoor climate, in the building lifecycle. In addition, its massive impacts and contribution to construction projects delivery for both Public and Private are visible for all to witness. The construction industry is a fragmented sector and it functions in an environment that is uncertainty and fast changing in its knowledge management as documented by (Dave and Koskela, 2009).

There is always the need for organizations to move in the direction of new knowledge of bettering their various businesses in the construction industry. The same story cannot be said in the Sub-Saharan Africa country of Ghana because through the researcher interviews and data collected, the construction sector in Ghana do not use BIM technology but most buildings types constructed are conventional buildings with CAD-based design. The question is ***"how to adapt and implement the knowledge of Green BIM concept into construction market in Ghana?"*** In order to improve its construction processes and projects delivery system for Architects, Engineers, Contractors and Facility Managers Industry. Ghana as of today, is experiencing fast growth in Population, urbanization, and a relative boom economic. These phenomena are putting increased pressure on the construction industry to build new homes and industrial buildings that are environmental friendly with modern technology for a faster-pace of building erection. *"Transforming buildings and infrastructure to become more sustainable elements of our built environment is a key challenge for the property, construction, planning, design and facility management industry, as well as governments at all levels" (Newton, et al., 2009).* However, there is still limited knowledge on the new trend of technology such as Green BIM in the Ghanaian construction industry , which government can make policies and laws through parliamentary instruments to enhance it use by all construction companies and individual alike for the execution of new projects as been practices worldwide.

In fact, it's fair to mention some of the challenges that Green BIM concept could addressed for the Architects, Engineers, Contractors and Facility Management in the construction sector in Ghana such as lack of good collaboration between project teams, Lack of analysis on energy usage on building projects, Deficiencies in project scheduling and time management, Non-function maintenance culture on constructed buildings, Ineffective mechanism for costs control, Projects overruns its costs due to delays in construction etc.

The introduction of Green BIM construction is not a new practice in the Scandinavian countries (Denmark, Sweden, Norway and Finland) and United Kingdom. There are leading construction companies like Skanska, (2015) which uses this Green BIM concepts in its various projects in the Nordic regions and the documented results of the company achievements with this philosophy are overwhelming. In an attempt to adopt the Scandinavian and United Kingdom model of Green BIM concept into the construction market environment in Ghana.

This research work will investigate how the Scandinavian countries and United Kingdom experiences on working with Green BIM concept in their projects delivery and construction Management.

Additionally, the study seek to evaluate the benefits of this concept implementation and the challenges that come with it use.

Afterwards, one could fairly ask, ***how will Green BIM concept improve project management team's collaboration, efficiency in information sharing, project scheduling and projects delivery system for Architects, Engineers, Contractors and Facility Management industry in Ghana?***

Obviously, the future for the construction industry in Ghana is not the conventional building style of construction that are not sustainable. That is why a new technology has to be adopted and these can only be done well, when all stakeholders in the industry come on board with their financial supports and professional knowledge in order to build well class projects that are eco-friendly. In the light of this, ***are stakeholders open to adopt the Green BIM philosophy in execution of new projects management in the construction industry in Ghana?***

This research report will takes into account the technological benefits, strategic advantage and operational flexibility that Green Building Design concept with BIM technology had created and its impact in project development in Scandinavian countries and United Kingdom for Architects, Engineers, Contractors and Facility Managers industry to the new construction market.

1.2 Ghana – New Construction Market

Introduction to the National Setting.

The national setting of Ghana is grouped into three environment, namely Political, Economic and trade and investments. This sub-chapter gives a little historical backgrounds on the New Construction Market - Ghana and the way forward for the Ghanaian construction industry and the opportunities that exist within the industry where other investors can explore and again, the local firms could also take advantage with the right kind of modern technology and technical known-how for the 21st century construction practices or concept.

1.2.1 Political environment - Republic of Ghana is a sovereign nation in West Africa. In 1957, Ghana became the first Sub-Saharan African nation to gain its Independence from the British, their colonial rulers. Ghana shares neighborhood borders with countries like Burkina Faso to the North, Ivory Coast to the West, Togo to the East and the Atlantic Ocean to the South. Ghana has a population of 27 million and the country is divided in ten (10) administrative regions. Ghana is well-known for its Tropical Climate, the northern part of the country is dry and hot, eastern coastal belt is relative warm and humid & hot in the south-west of Ghana.

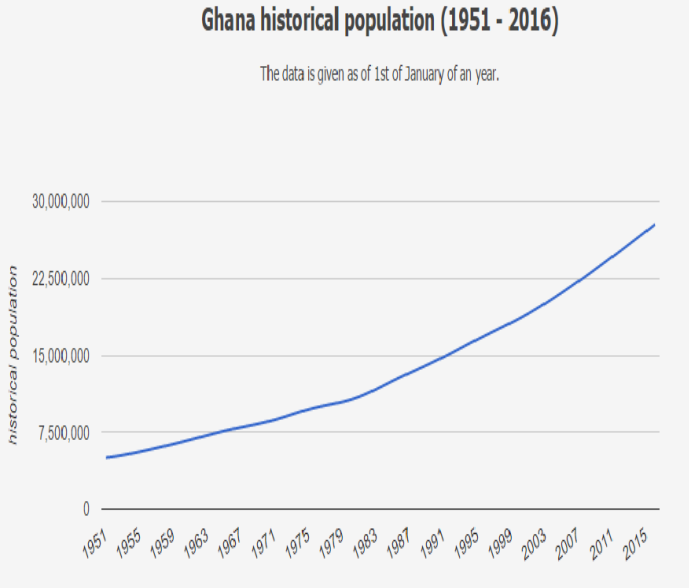


Fig.1: Ghana Population

Source: *UNESCO Institute for Statistics*

Fig.2: Republic of Ghana Map

Source: *Danida, 2014*

Denmark is among the first western nations to recognize Ghana independence. The first president Dr. Kwame Nkrumah vigorously promoted Pan Africanism and a key campaigner for the fight against apartheid and colonialism in Africa. In 1992, Ghana introduced democracy rule after two decades of turbulent military rule. The country is now enjoying peace and stability in developments. The Institute for Economics and Peace rated Ghana the 6th most peaceful country in Africa (GPI 2016).The international world sees Ghana democracy as good model for other African countries to emulate. Ghana is a key member of the African Union (AU) and the Economic Community of West African State (ECOWAS) for vigorous foreign and security policy.

Since 1992, Ghana has conducted peaceful, free and fair election. Most importantly, one of the first countries in African to use biometric system to vote in their election in 2012. The civil and political rights of all citizenry are respected nationwide but there is still some challenges like nepotism, corruption in the business environment. (Danida 2014)

1.2.2 Economic environment – In recent years, the economic growth indicators are steady and positive for Ghana. In July 2011, Ghana was recognized as lower middle income country according to World Bank country classifications.

There was 15 percent growth rate, and it was seen as one of the highest in the world on that year. Unfortunately, there was decline of 7.9% and 7.4% respectively in growth from the year 2012 - 2013. The factors that ignites the high growth rate was the oil exploration and also, the traditional sector products such as timber, gold, cocoa did contributed to that effects too. One disturbing factors to all these commodities especially gold, is the increase illegal mining that are causing environmental degradation and depletion of natural resources due to the high gold prices in the world market. This phenomenon is causing conflicts among the local population and foreign miners, most notable are the Chinese nationals.

The decline of the economic growth rate has compelled the government of Ghana to intensify its focus on Public Private Partnerships (PPP), Private sector development and job creation in order to improve the decline growth situation of the economy. The macroeconomic situation did shown relatively positive indicators in regards to inflation and fiscal balance but lost control after the end of year 2011. The idea to adopt to development strategies by the government is to improve Ghanaian business environment and this resulted it to be ranked 67th in World Bank's Ease of Doing business 2014. However, the country macroeconomic performance indicators has declined and deteriorating according to Economic Forum's Global Competitiveness report 2013 - 2014.

In addition, climate change and Ghanaian population is increasing rapidly and it's a threat to the environment and natural resources most especially, unplanned urbanization. There are opportunities in the market to adopt to Knowledge transfer programmes and Green Technologies such as wind energy and solar as form of innovative climate solutions to minimize the effects on the environment. (Danida 2014)

1.2.3 Trade and Investments – Ghana business environment is liberal on import policies and this has boosted its economic growth in the market. However, there is a change in lifestyle for the ever-increasing Ghanaian youth population due to rising of middle-class income status in our society. This has resulted to paradigm shift in citizenry consumption behaviour in higher demands for services and goods. An estimated population of 51.9% lived in urban localities in the year 2011. As a results of increasing wealth among the citizenry, there has been a decline from 51.7 percent in 1991/92 to 28.5 percent in 2005/06 of people in the nation living below the poverty line. In 2012, the total imported goods to Ghana were estimated at US$17.8 billion and US$13.5 as exports. The European Union (EU) accounted for total imports of 21.9% whilst 47.7% for the total exports. The initial end of year projected deficit was US$4.957.5 million as against an estimate of US$4,046.3 million on drop projected imports in the year 2013.

There are many countries that trade and invest into the Ghanaian market namely Denmark, China, USA and so forth. Denmark export chemicals, machinery and transport equipment, food products, pharmaceutical products and technical knowhow to Ghana. In other hand, Ghana exports fruits, cocoa, oil seeds and biomass. One can found Danish companies like Maersk Group, Novo Nordisk and Grundfos trading in Ghana. As a matter of fact, due to the peace and political stability in Ghana, the country holds the key to provide the business platform hub to the regions in West Africa for trade and investment. The business environment in Ghana can access an estimated population of 250 million people within the Economic Community of West Africa States (ECOWAS) market. In spite of huge potential market, there is some challenges like the harmonization of laws and regulations that needs to be addressed in order to have a free trade among member states. (Danida 2014)

1.3 Ghanaian Construction Industry

Ghana is one of the principal investment destination market due to its status as one of best well-governed nations in Sub-Saharan Africa. The Ghanaian construction industry is vibrant and a key contributor to the national economy. The two main State institutions responsible for the infrastructure developments for the citizenry are Ministry of Works, Water Resource and Housing, in-charge for housing developments of which the construction industry falls under its authority. The second one is the Ministry of Roads and Transportation, basically oversees all civil-engineering infrastructures in the country (Kwadwo, Osei, and Kwasi 2013). The increasingly participation by the private sector in the areas of real estate development, construction of Hospital, School, factories, etc. and Government investments in infrastructure nationwide as turned out to be a major driver of growth of the economy. As matter of fact, in the developing countries like Ghana, the Government in Power has a huge influence in the built environment in terms legislations and policies within the construction industry. In view of that, the Ministry of Works, Water Resources and Housing liaisons the political agenda of the government to construction companies on developmental projects (Laryea 2010).

According to Ghana Statistical Service, (2014) the industry sector of Ghana economy of which the construction industry is part of it recorded the highest growth of 9.1% in 2015 as compare to the Agriculture and Service sector of the economy.

		2007	2008	2009	2010	2011	2012	2013	2014*	2015**
1.	**AGRICULTURE**	**-1.7**	**7.4**	**7.2**	**5.3**	**0.8**	**2.3**	**5.7**	**4.6**	**0.0**
1.01	Crops	-1.3	8.6	10.2	5.0	3.7	0.8	5.9	5.7	-1.7
	o/w. Cocoa	*-8.2*	*3.2*	*5.0*	*26.6*	*14.0*	*-9.5*	*2.6*	*4.3*	*3.5*
1.02	Livestock	4.7	5.1	4.4	4.6	5.1	5.2	5.3	5.3	9.3
1.03	Forestry and Logging	-4.1	-3.3	0.7	10.1	-14.0	6.8	4.6	3.8	1.6
1.04	Fishing	-7.2	17.4	-5.7	1.5	-8.7	9.1	5.7	-5.6	5.3
2.	**INDUSTRY**	**6.1**	**15.1**	**4.5**	**6.9**	**41.6**	**11.0**	**6.6**	**0.8**	**9.1**
2.01	Mining and Quarrying	6.9	2.4	6.8	18.8	206.5	16.4	11.6	3.2	-3.8
	*o/w. Oil****	-	-				*21.6*	*18.0*	*4.5*	*2.2*
2.02	Manufacturing	-1.2	3.7	-1.3	7.6	17.0	2.0	-0.5	-0.8	-2.0
2.03	Electricity	-17.2	19.4	7.5	12.3	-0.8	11.1	16.3	0.3	3.2
2.04	Water and Sewerage	1.2	0.8	7.7	5.3	2.9	2.2	-1.6	-1.1	15.6
2.05	Construction	23.1	39.0	9.3	2.5	17.2	16.4	8.6	0.0	30.6

Fig.3 Growth Rates of Gross Domestic Product at 2006 constant prices (%)

Source: Ghana Statistical Service

The Ghana Statistical Service annual report did emphasized that the Industry sector of which the construction industry is part of, is the largest activity with a growth of 30.6% and 14.8% respectively, a share nominal GDP. The Industry sector share increase slightly in 2015 as of 26.9% as against 26.6% in 2014.

		2006	2007	2008	2009	2010	2011	2012	2013	2014*	2015**
1.	**AGRICULTURE**	**30.4**	**29.1**	**31.0**	**31.8**	**29.8**	**25.3**	**22.9**	**22.4**	**21.5**	**19.0**
1.01	Crops	21.3	20.3	22.4	23.6	21.7	19.1	17.2	17.4	16.8	**14.6**
	o/w. Cocoa	3.0	2.7	2.5	2.5	3.2	3.6	2.6	2.2	2.2	**2.1**
1.02	Livestock	2.5	2.3	2.1	2.0	2.0	1.8	1.6	1.4	1.2	**1.2**
1.03	Forestry and Logging	4.1	4.2	3.7	3.7	3.7	2.8	2.6	2.2	2.3	**2.2**
1.04	Fishing	2.5	2.3	2.7	2.5	2.3	1.7	1.5	1.4	1.2	**1.1**
2.	**INDUSTRY**	**20.8**	**20.7**	**20.4**	**19.0**	**19.1**	**25.6**	**28.0**	**27.8**	**26.6**	**26.9**
2.01	Mining and Quarrying	2.8	2.8	2.4	2.1	2.3	8.4	9.5	9.4	8.0	**6.4**
	*o/w. Oil****	0.0	0.0	0.0	0.0	0.4	6.7	7.7	8.2	7.2	**6.0**
2.02	Manufacturing	10.2	9.1	7.9	6.9	6.8	6.9	5.8	5.3	4.9	**4.7**
2.03	Electricity	0.8	0.6	0.5	0.5	0.6	0.5	0.5	0.4	0.4	**0.4**
2.04	Water and Sewerage	1.3	1.0	0.8	0.7	0.8	0.8	0.7	0.6	0.5	**0.6**
2.05	Construction	5.7	7.2	8.7	8.8	8.5	8.9	11.5	12.0	12.7	**14.8**

Fig.4 Distribution of Gross Domestic Product by Economic Activity (%)

Source: Ghana Statistical Service

1.4 Construction market opportunities

The emergence of the oil and gas industry in Ghana since 2011, has provided new opportunities for the exploitation in the construction market. The high demands for modern infrastructures to enhance the business environment operations due to current oil discoveries and the construction climates in Ghana is of a strong desire. The attraction for the influx of foreign construction companies in the construction industry as results of developmental projects going on nationwide is not of a surprise. These foreign firms are well equipped with advance technologies that enable their organizations to have competitive advantage over the indigenous construction firms. The technological knowledge credentials of these firms, helps in winning most of the million dollar contracts from the Government. On the platform of globalization in business the local companies needs to invest in technology like building information modeling (BIM) in their project management and research programs which will help the industry to compete well with their foreign competitors. The end results of these investments will yield growth in their businesses and will leads the built environment towards sustainable developments. The citizenry in other hand, will have job opportunities to better their livelihood and develop their various professions in the construction industry in Ghana.

1.5 Motivation for the Research

The concept of Green Building Design with Building Information Modeling (BIM) technology has been used in many projects within the built environment in the western world. Surprisingly as it may sound, most construction companies in sub-Saharan African countries like Ghana has not adopt to this concept of project execution yet and again, even some universities do not have literature materials for this concepts. The researcher purpose to conduct this research on this topic as follows;

1. This research work seek to further broaden the existing literature and the knowledge base on the Green BIM concept from the western world into a new market in the sub-Saharan African country like Ghana.
2. This study will serve as a template for both academics and stakeholders in the construction industry in Ghana to embrace and adopt the Green BIM concept in their project delivery system and construction management within the Built Environment.
3. The study will provide sound platforms for Government's to make policies and laws through parliament as practice in Scandinavian countries (Denmark, Sweden, Norway and Finland) for the

Architecture, Engineering, Construction and Facility Management Industry (AEC/FM Industry) in their various project works.

4. This research work outcomes will equip the AEC/FM Industry with New Technological tools in dealing with project cost estimation, efficiency in projects information sharing, project team's collaboration, accuracy in project scheduling, 3D Visualization models, analysis on energy usage in building projects etc. in their day to day operations in the construction industry.

1.6 Objective of the Research

The quest to comprehend the dynamics of Green Building Design with BIM Technology concept into a new construction market in Ghana as follows;

1. To give clear understanding of the Green BIM concept and how this new technology can transformed the construction industry market in Ghana when adopted.
2. To investigate the Green BIM concept development in Scandinavian countries and United Kingdom. What are their experiences and impacts on working with Green BIM concept in their projects delivery and construction management?
3. To explore the technological benefits, strategic advantage and operational flexibility in Green Building Design concept with BIM technology had created in the Built Environment in Scandinavian.
4. To give a roadmap to transfer and implement the Scandinavian and UK model of Green BIM concept into the new construction market in Ghana.

1.7 Initial Problem Statement

The construction industry problems and challenges are nothing new to be surprise about but it scale of magnitude that affects the success of project execution is what bring concern to the built environment industry players and stakeholders worldwide. The Ghanaian construction industry is no exceptional, its share of this phenomenon within the Architecture, Engineering, Construction and Facility Management industry (AEC/FM Industry) are voluminous. This study will narrow the problem areas of investigation to some **inefficiencies in relation to organizational management and the deficiencies in technological upgrades for effective operational process or methods within the Ghanaian construction industry,** and this will be in the main problem statement for this research work. Subsequently, how best to incorporate modern technology and innovative strategy to address the challenges identified through the survey and interviews conducted will be proposed in the chapter 7.

However, there are numbers of literatures that has been published on the challenges affecting the construction industry in Ghana in different angle as documented by others researchers.

Laryea, (2010), identified the challenges affecting the contractors in the construction industry in Ghana and can been grouped into three (3) environmental factors, namely, political, economic and legal. The researcher interviewed seven building and civil engineering contractors and six contractors in road construction. More so, the period in which this research data was collected was in 2009 and 2010. The findings on the challenges base on the two categories of contractors in the construction industry as documented by the researcher as follows;

1.7.1 Contractor (A) – Building and Civil Engineering: the results of challenges that affects Contractor (A) are Design problems, Managerial and supervision of contracts, and financial issues.

- **Design Problem:** Most contractors complains poor design works which lack better understanding and details. The consequence of this effect call for several meetings with the design teams and it slow down the workflow of all trades undertaken on the said project. Sometimes, the building owner's wishes is not well documented during the beginning of the project. Lack of documenting these important information in the tender documents affects the various construction phases and at the same the profit margin of the construction company in question is also affected.
- **Managerial and Supervision of contracts:** Lack of qualified construction professional with the technical know-how is missing in project management and execution as explained by the contractors. Most of these tradesmen (artisans) on the construction sites needs training in order to carry out work but their excuse is that, they had been working in the construction site for many years so they do need traineeship. Management of projects cannot in any given situation underrated due to its huge capital investment, so there is always the need for good personnel with modern construction knowledge to handle and supervise project works.
- **Financial Issues:** One of the biggest problems that contractors do encounter day in and day out is cash flow. Most of the interviewed contractors expressed their frustration in payment of project execution most especially from governmental projects. Any time there is delay in payment, banks finds it difficult to offer contactors funds for their project and sometimes, these cash comes with high interest because the banks consider these contractors as higher risk.

1.7.2 Contractor (B) – Road Construction: the results of challenges that affects Contractor (B) are Funding, Politics and Complex payment procedures.

- **Funding of Projects:** Project funding problem does not only affects construction works but retention of good professional personnel in the road construction industry too. Sometimes, lack of funds delays the payment of staff salaries or paid less depend on the situation at hand. More so, this same funding make it difficult for contractors to buy modern equipment's to enhance their operations. It sad to note that some of the equipment is more than 30 years old and it efficiency level is very low said by one contractor. The results of equipment breakdown is frequently and the risk of uncertainty for its use very high. The banks feels reluctant to give credits to these contactors in view that, there is always unusual delays in payment of credit. The contractors provide collateral if they go in for banks loan, so most of the contractors rely on overdraft facilities from the bank.
- **Politics:** In sub-Sharan African country like Ghana, politics affects every activities and its environment. The frustration in contracting in Ghana is overwhelming. As a contractors the more you are affiliated with the government in power, the more likely the contractor get contracts to execute. Sadly as it may sound but one cannot overlook of its effects to construction industry and its business environment in general. The reason been that, some politicians used these contactors as a source of getting money to champion their political campaigns.
- **Complex payment procedures:** Contractors in the construction industry in Ghana do face problem of payment of project completed. Most road construction projects in Ghana are funds by the government, Revenue generated by payment of road tolls, Donor agencies and Consolidated Fund. The payment and release of fund is a problem, the structure of payment for contractors are very complicated due to the level of bureaucracy. Firstly, the government has to give the approval for payment, then Ghana Parliament must rechecked and approved the total amount of payment and finally, the Ministry of Finance will pay the project money to the contractor. This circle of payment structure can take months before the contactors received the money invested in the given project work.

Similarly, another set of researchers' contribution to challenges that causes delays in building construction projects in Ghana. Fugar & Agyakwah-baah, (2010) stated that, about 9 areas that affects Clients,

Contractors and Consultants in line of delays in project executions are Financing of projects, Scheduling and Controlling Techniques on projects, Contractual Agreement/Relations, Changes in Drawings and Clients Wishes, Material Supplies, Government actions/inactions, Manpower – Skilled/Unskilled professional, Environment conditions and Equipment capabilities. The above fore mentioned problems and challenges gives a vital overview on some of factors affecting the construction industry market in Ghana.

1.8 Research Questions

In reflection to the aforementioned objectives, this research work specifically seeks to address the following questions in respect to the thesis topic

Primary Question:

1. How to adapt and implement Green BIM concept into the construction market in Ghana for AEC/FM industry?

Secondary Questions:

2. Are stakeholders open to adopt the Green BIM philosophy and what are their perception of it uses on execution of new projects management in the construction industry in Ghana?
3. How will Green BIM improves project management team's collaboration, efficiency in information sharing, project scheduling and project delivery system for AEC/FM industry in Ghana?
4. What are the barriers for the success of Green BIM concept adoption and implementation for the AEC/FM industry in Ghana?
5. What are the factors necessary for capacity building for industrial players and the future on Green BIM adaption into the new construction market?

Chapter 2: Research methodology

This chapter describes the roadmap aimed to help the researcher and reader as well, the opportunity to have an overview image on how this thesis report was developed and adopted to bring to light the purpose of this research work. Additionally, it gives description of the general approach to the entire thesis structure and also shows the steps taking to present the methodology approach on this research report as shown in figure 5.

2.1 Introduction

This thesis report is a "Desk and Field Research". The meaning of the term Desk and Field research is that some of the information can be obtained indoor via literatures (books, journal etc.) whilst the field is to go to companies for interviews in order to have the needed information or data. The methodology for this dissertation would be Mixed Methods Research (MMR), where Qualitative and Quantitative means of collecting data would be deployed to gather, evaluate and analysis data by the researcher on the need for the adaptation of Green Building design concept with Building Information Modeling (BIM) into the new construction market. Furthermore, the findings of the collected data will addressed the research questions posed in this research work in Chapter 1.8

In the account of the investigation and documenting of this thesis report on the need for adaptation of Green Building Design concept with Building Information Modeling (BIM) into the new construction market – Ghana in the Architecture, Engineering, Construction, and Facility Management Industry (AEC/FM Industry). The researcher grouped its methodological strategy into three main sections. The following are the highlights of the research works as mentioned in this chapter.

- Literature Reviews
- Mixed Methods Research
- Analysis and Discussion

2.2 Literature Reviews

Literature reviews are one of the essential tools for data collections in research work and it has contributed enormously in many years in the field of research environment. In this thesis report, some of the motives behind every literature reviews or bibliographic research as follows;

1. To broaden one knowledge on research work done by other researchers on a given subject or topic
2. To discover new angle of argument for a situation which is of concerned to society or professional bodies etc.
3. To build upon on established findings to which it will make industry efficient, enhance the use of technology and creating comfort for human life, plants and animals at large.

In reflection of the above statement, an extensive scientific literatures and journals has been reviewed in this thesis report, aiming to discover what has been researched upon in relation to Green building Design concept and Building information modeling (BIM) worldwide and the collected information gathered serve as a base of contribution to the research questions in chapter1. The three main source of knowledge acquisition and information collection on this thesis report are as follows;

- Scientific Papers/Journal from the internet; (www.researchgate.net, www.sciencedirect.com, www.itcon.org, etc.)
- Aalborg University Library (www.aub.aau.dk); the researcher made good use of AAU facility, hardcover books, Journal, online books pdf and other students project as means of inspiration and motivation for the writing of this report.
- Books on Thesis topic; the researcher buying some personal books which was not available at university library.

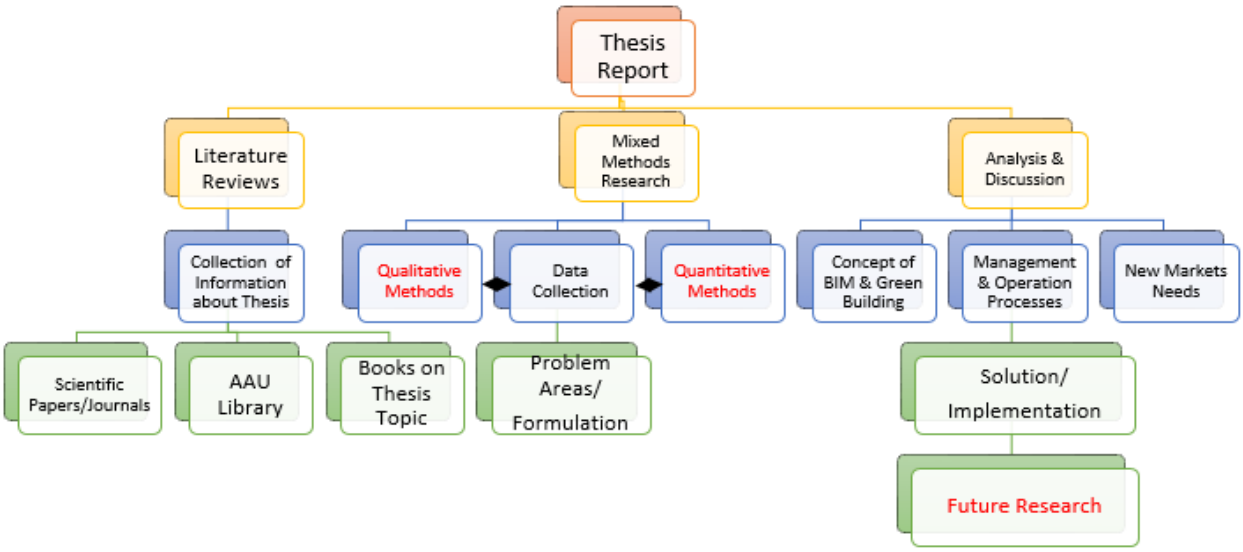


Fig.5 Framework for Thesis Report Structure

2.3 Mixed Methods Research (MMR)

According to Creswell, (2014) Mixed Methods Research it is the methods which qualitative and quantitative research is used to collect data by way of integrating the two data gathered. This design structure provides a better understanding of the research problem by comparing, relating and interpreting the data gathered for comprehensive results outcomes. Again, it can be either theoretical frameworks or philosophical assumptions. In the account of the research questions (chapter 1. 8) in mind, the research motive and choice of consideration for Mixed Methods Research is able used this method to have full knowledge and understanding on how Green BIM is implemented in the Danish Construction industry and also, test the perception level on Green Building with Building Information Modeling in the new construction market (Ghana).

This in a long run, will provide the researcher the best framework to recommend practical solutions in respect to the research questions for this thesis report. The figure 6, shows the characteristics of Mixed Methods Research.

Quantitative Methods	Mixed Methods	Qualitative Methods
Pre-determined	Both predetermined and emerging methods	Emerging methods
Instrument based questions	Both open- and Closed-ended questions	Open-ended questions
Performance data, attitude data, observational data, and census data	Multiple forms of data drawing on all possibilities	Interviews data, observation, document data, and audiovisual data
Statistical analysis	Statistical and text analysis	Text and image analysis
Statistical interpretation	Across databases interpretation	Themes patterns interpretation

Fig. 6. Mixed Methods Research Source: Creswell, (2014)

2.3.1 Data Collections

In this thesis report, the concept of Data collections used are grouped into two in this research work, namely Qualitative and Quantitative methods.

- **Qualitative Method** – In this form of data collection involved, Interviews in Denmark and Ghana, skype (online communication), e-mail communication, and Phone communications. In all, the researcher was granted three interviews and open-ended questions were used, in order for the respondents to have the opportunity to contribute to the thesis topic freely. (See Appendix B, C, D)
- **Quantitative Methods** – With this form, online Questionnaires survey (www. surveyxact.dk) was designed to enable the researcher to gather, evaluate and analyze the opinions from sizable number of respondents from the Architects, Engineers, Contractors, Project managers, Facility managers and other stakeholders in the Ghanaian construction industry in relation to the thesis title and research questions. In the survey, both open-ended and closed-ended questions were used. (See Appendix A)

The outcomes of the analysis of these data collections will enable and enhance the argument for the need for adaptation and implementation of the Green BIM concept in the construction industry in Ghana.

2.4 Analysis and Discussion

Due to limited time, the researcher opted for the Concurrent approaches within the Mixed Methods Research for the data collection. The idea was to collect primary data alongside secondary data at the

same time and then, compare or relate the information collected as results of the qualitative and quantitative methods used. This will provide the researcher the platform to interpret the collected data and used to address the research questions in this research work.

The fig.2.3 shows Convergent Parallel Mixed Methods Research adopted by the researcher to analysis and interprets the collected data for this thesis project report.

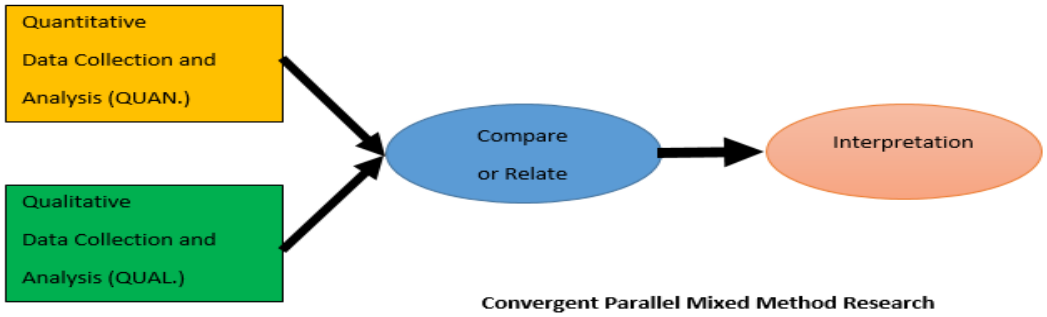


Fig. 7 Convergent Parallel Mixed Methods Research Source: Creswell, (2014)

On the discussion part, the researcher evaluate the importance of BIM and Green Building concept in a broader perspective to the Ghanaian construction market. The focal areas to identify problems affecting the industry is management and its operational process and the results of survey data collected will be used to solve or addressed the research questions. With the data in hand, the research will propose the best solutions possible for the new market needs. All these will be in line with goals for this thesis report and with consultation with the researcher thesis supervisor.

2.5 Ethical concern for the Research

In research work, it extremely important for one to protect or safeguard information confidential given by an individual or organization in respect to data collection on the research work. This thesis report has been conducted in civil and professional manner most especially handling of information given, whereas the researcher in the other hand, explained the importance of the research work to the companies and individuals in question, in order to establish trust and fair play as they contribute in the work of this thesis report.

All the viewpoints of the respondents who participated in the survey and the series of interviews are respected and protected to avoid any bias opinions as the researcher document it findings. In view of that, the researcher did not allowed any personal views to affects the collective effort on the subject matter under scrutiny.

3.6 Limitation of Research work

In every research work, there are always limitation and challenges associated with it. In light of that, this thesis report is no exception. The main challenges encountered by the researcher during the writing of this project was the difficulty for construction companies in Denmark and Ghana to grant the researcher request for an interview in line to this thesis work. It was frustration during that time, but with determination and fellow-ups, finally, three companies open their doors for some interviews.

Secondly, some of the quantitative research respondents shows unenthusiastic attitude in answering the survey questionnaires, so the population who took time off to answer the questionnaires were not as high as the researcher expected.

Lastly, project report time was limited to expand the research subject base to new territories and language barrier also contribute some headache to this research work, especially some of data the researcher received was in Danish language, so there was the need for translations.

Chapter 3: Literature Reviews

In this chapter, in order for the researcher to adopt the best green building design solutions with BIM technology for the Architecture, Engineering Construction and Facility Management Industry in the construction sector in Ghana. The researcher conducted a comprehensive literature reviews on series of researcher's papers to discover what has been researched about on Green Building Design concept and Building Information Modeling (BIM) globally . Again, to evaluate the source of contribution to the subject under discussion and further build on the established findings with good answers to resolve any contradiction if possible.

3.1 Building Information Modeling (BIM) Technology

Even though the use of technology in the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry is not a recent development, Building Information Modeling is however a current development in the built environment. Earlier implementation of digital model technology have enabled tools in the building industry includes 2D and 3D computer-aided design (CAD). As an innovation, BIM is more than a software but rather a new design paradigm and methodology using sophisticated computer tools (Krygiel and Nies 2008). Seen as a solution for the many challenges which bedevilled the paper based drawings in the building environment, Eastman, Teicholz, Sacks, & Liston, (2011) defined BIM as a *"modeling technology and associated set of processes to produce, communicate, and analyse building models"*. From another perspective, Building Information Modeling (BIM) is seen *as "an intelligent model–based design process that adds value across the entire lifecycle of building and infrastructure projects"* (Autodesk Inc., 2011). The transformative role of BIM in the AEC/FM industry is associated with its provision of consistent data for coordination and collaboration among all stakeholders involved in a building design. BIM facilitates cross function team collaboration among architects, engineers, contractors and facility managers because it is a new approach to building (Autodesk Inc. 2011).

In a study to position how BIM technology is understood in the AEC/FM industry, Gu & London, (2010) made some interesting discovery with respect to people, process and product. The authors conducted the study in two Australian capital cities; Sydney and Brisbane through focus group interviews.

The key participants of the interview were design consultants, project managers, architects, engineers, contractors, facility managers, government delegates, software application vendors, service providers and academics. According to their study, BIM means different thing to contractors, project managers and architects. For project managers and contractors, BIM technology is an intelligent database management system that directly extracts and analyse data from Computer Aided Design (CAD) for cash flow modelling, simulations, time sequence and risk scenario planning over the lifecycle of a building project. Design disciplines such as Architects and Engineers have a different expectation because for them BIM is an extension to CAD. However, all players in the industry emphasises that BIM technologies enables enhanced and integrated document management, visualisations and navigations (Gu and London 2010).

This study adapts the definition from Krygiel & Nies, (2008) and state that BIM is the "establishment and implementation of a technologically coordinated and consistent data and information about a construction and infrastructure project with sophisticated modelling and predictions from the conception to the demolition of the project which requires cross collaboration among all partners involved in the building project".

3.2 Benefits of BIM Technology Implementation

BIM technology has been hailed as having a lot of benefits for the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry. This section of the literature reviews will provide some of the benefits below.

Although BIM Technology adaption is in the early stages, the cost benefit effects are seen as the most significant impact as it reduces waste and increases profitability. As a new way of working among key stakeholders involved in a building project, BIM is seen as having cost efficiency benefits for the AEC/FM industry. Giel & Raja R. A. Issa, (2013) indicated that the coordinated documentation across teams involved in a BIM project led to high returns on investment and cost reduction benefits for construction companies because it allows early discovery and correction of major contradictions during preconstruction as well as quicker detection of dimensional discrepancies in documents for building projects. BIM driven projects lead to greater efficiency and effectiveness from better and informed decision making because, team members have access to information and data during the project lifecycle.

In addition, Azhar, (2011) who conducted a four case study to evaluate the costs and risks associated with BIM technologies in Georgia, stated that the increased integration and coordination enabled by the technology led to a 64% profitability/return on investment (ROI).

Likewise, Eadie et al., (2013) conducted a study in the UK, on the implementation of BIM across the project lifecycle of an infrastructure, and concluded that its cost reduction effects was the most significant practical benefit for stakeholders. 92 respondents answered and returned an online questionnaire investigating BIM technology in the project lifecycle. The argument for approaching the study form the project lifecycle perspective. The project lifecycle is mainly from conception, design, construction, facilities management and demolition. Even though, BIM has been studied from different angles, the researchers contended that because the study is in its early developments, studies have not been done in the demolition aspect. This current project will adopt a holistic perspective and include how BIM can be used in from the whole of the project lifecycle in the Ghanaian context. The other benefits that the authors revealed in order of importance to the respondents were increased collaboration, improved process management, waste reduction and heightened accuracy in project implementation. Furthermore, according to the respondents, BIM technology was highly used in the design and pre-construction stages of the project than in the construction phase of the project with only a 10% adoption rate for the operation and management stages. (Eadie et al. 2013)

Similarly, an industrial perspective by Autodesk, (2011) added to the findings above by indicating that BIM technology allows AEC professionals and building owners to digitally "design, visualize, simulate, and analyse the key physical and functional" features of a building project before physically building it. In their own word, Planners can select optimum sites for the project. Architects has the means to design more accurately with less waste of time, fewer technical errors which in turns match the building owner wishes and vision. Engineers have a quicker responses from Architects due to good coordination and other engineering disciplines, this enhance design consistency and good flow of work. Contractors make sure to rectify any issues related to constructability and this is down at the early stage of project execution in order to avoid any expensive expenses on changes in design Building Owners has the possibility to make good use of the building models now and into the future. This serve a basis tool to guide the facility and its asset management program. (Autodesk Inc. 2011)

As I have demonstrated above, BIM Technology has made positive impact in the Built Environment and thus has potential for the Ghanaian AEC/FM industry. It is important to point out in this review that BIM has been studied across different countries. BIM technology has been studied within Australia (Gu and London 2010), UK (Eadie et al. 2013), USA (Azhar 2011) and within the four Scandinavian countries (Wong, WONG, and NADEEM 2013). This shows that BIM Technology is a global practice that is not location specific and therefore can be used in Ghana and therefore, this study is a step in the right direction.

3.3 Challenges in BIM Technology Implementation

BIM Technology has a lot of benefits and its adoption has been emphasised in the literature but its implementation is not without challenges. This section of the literature review intends to look at some of the challenges that Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry faces in the implementation of BIM Technology.

In a recent editorial, Gerrish, Cook, & Ruikar, (2016) listed these as the challenges facing the implementation of BIM Technology in the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry.

- Inadequate datasets and information inhibits the full potential of BIM as BIM Technologies effectiveness depends on the information available.
- The inability of current industry players to manage and utilize the potential of BIM Technology because of lack of requisite knowledge and skill sets also prevents many companies involved in the industry to utilize it.
- Difficulties in integration between design platforms and operation systems for smooth running of BIM Technologies
- Compliance issues with regards to adaptation to local regulations and standards in practice and theoretically.

Eadie et al., (2013) confirms the above observation by also establishing that the major challenge that hinders the adoption and implementation of BIM Technology for infrastructure development is related to the lack of requisites know-how and expertise for its implementation. Furthermore, Gu & London, (2010) also stated that, there is the need for new capabilities and competencies like the BIM manager especially in large scale projects if BIM technology is to be successfully implemented. This is because, BIM technologies require a change in the conventional individualistic work practice among parties to a cross

functional team based work where all stakeholders involved in the project actively contribute to a single shared model with agreed protocols and standards (Gu and London 2010).

Also, there are legal issues such as data ownership and the risk of loss of proprietary information due to the fact that BIM Technologies requires information sharing among players in the Building Environment (Azhar 2011). There is no clear cut and well-developed practical strategies for the protection of data and information as it is shared and exchanged in among partners in the building information model components. Akhar, (2011) believes that this challenge can be mitigated by use of contracts so as to safeguard against data misuse and theft.

In summary, although BIM Technology has some risks and challenges, its significant potential overshadows its risks and challenges and this is the stance of the current study.

3.4 Green Building Design

The concept of Green Building or sustainable building represents a change in the design and construction of building to maximize the quality of the built environment with a focus on reducing the negative impact on the external environment from the building project (McLennan, 2004).

According to Wolley (2013) Green building is more than protecting the external environment rather it holistically involves assessing the potential and future impact of the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry activities on humans and the ecology through energy conservation methods.

The benefits of green building has been documented in research. From a longitudinal research where respondents were divided into two groups with one group in green building and the other in a traditional building, Thatcher & Milner, (2016) concluded that green buildings led to improved health status among occupants of the green building. Furthermore, the working atmosphere was enhanced for the workers who occupied the green building as against those in the traditional building. Green building is seen as an integral part of the building project and this is why in Switzerland there is a group called "Network for Sustainable Construction Switzerland" who coordinate the activities of all partners involved in the built environment (Feige, Wallbaum, and Krank 2011).

Green buildings increase energy efficiency because the longevity of buildings require that if it was constructed in a sustainable method it will have a long term effect on the wider environment.

Also, green building initiatives are cost efficient and can be implemented through technological means. The above discussion is a summary of a research undertaken in Asia by M. P. Laurenzi, (2007). From a cost data perspective, using 18 government buildings in India, Vyas & Jha, (2016), the key aspects of green building are low-impact design, an awareness of environmental impacts, design aimed at accessibility enhancement, the inclusion of construction management practices, a specialized structure for artisans involved in the building and lastly the use of approved recycled materials for the green building.

From the foregoing discussion, green building is an essential industry practice in the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry and thus cannot be underrated.

3.5 Green BIM Concept

Green BIM is the integration between Green building and BIM Technology. From an environmental, social and economic orientation, BIM Technology can impact green building in the project lifecycle. In the design phase, both economic and environmental considerations can be included when designers use BIM Technologies to assess the cost, risk and energy consumption of different models as a means to achieve green building objectives (Soltani 2016). Apart from the above, vast data sources available in BIM Technology when used by industry stakeholders to assess sustainability aspects including near zero carbon in construction, optimizing energy usage, optimizing the environmental performance, efficiency in managing waste, improvement on indoor climate in the building lifecycle leads to what we called Green BIM. However, Soltani, (2016) highlighted that the use of BIM Technology in the social aspects of green building such as the health and well-being of humans have been underexplored in research and this represent a gap in the literature.

Bonenberg & Wei, (2015) conducted a research is to investigate the use of BIM applications on Green buildings design structures in terms of green materials, energy efficiency, and lighting system through a project case study approach. The researchers' analysis indicated that the use of BIM helps to minimize waste and elevate quality of construction, in which the BIM tool provides the platform of visualization of digital building models in multi-dimensional digital design for Architects, Engineers, Contractors, and Developers. The use of BIM tools promote the integration of architectural design and natural environment. The provision of digital model on BIM use enhance analysis on project cooperation and collaboration in a multi-disciplinary projects in line with green design concept.

To add to the current discussion on Green BIM, Bynum, Issa, & Olbina, (2013) used survey questionnaires examined the mind-set behind the use of BIM technology for sustainable design and construction in the AEC/FM industry. They categorised the study from current use of BIM in design and building practices, the importance of sustainability in design and building practices and the BIM application to support sustainable design and building practices. The outcomes of the survey findings indicate that the current use of BIM in sustainable design and construction comes with these results; Out of 123 respondents, 89% use BIM in their operations, 51% had used BIM for the past 3 years, even though 63% agreed that the use of BIM and sustainable design is vital within the construction firms but the main purpose of the use these two concepts are for Visualization, project coordination and collaboration. However, under project delivery methods, 77% survey respondents, i.e. design/build (40%) and integrated project delivery (37%) agreed to the fact that, it provides a good platform for maximizing project delivery system by interlocking the use BIM as a sustainability tool in the AEC/FM industry. Whilst, 91% of the respondents do agreed that in the schematic design phase (40%), Design development (20%), Predesign stage (31%), are the best stage to implement BIM in sustainable design. The only problem affecting the potential of BIM use in sustainable design is the interoperability with the various BIM applications in the AEC/FM industry. The researchers called for further research to look into the effects on the use of BIM in sustainable design by the building owners/clients in the construction industry.

Even though some researchers have established that Green BIM is being implemented in the Architecture, Engineering, Construction (AEC) and Facility Management (FM) industry, Dowsett & Harty, (n.d.) took a different stance on the literature. Most of the literature on BIM and sustainable design emphasis on improvement but the argument always lack defined details of the narrative improvement, either technologies or quality of information. In most situation, the best practice neglect the importance of cultural environment that can affects the results of analysis and construction itself. Practitioners are advice to go along with culture of compliance and not to adopt to any strange innovative ideas which could create problems in the company's development. More so, BIM tools and methodologies must adhere to standardization methods and procedures in order not to disconnect the stakeholder's dialogue engagement. This will enhance decision–making and minimizing restrictive environmental conditions on conventional construction. Again, BIM methodologies and tools has the capability to solve problem associated with practitioners measurement methods but first, need to diagnose and then identify the conditions which will help in implementing the best technique that is of importance to the company and

projects. The range of opportunities of BIM adoption reshaped company's capabilities and add value to sustainable design (Dowsett and Harty n.d.). The contribution of another set of researchers consist in their development of a model as a means of integrating Green Building and BIM Technology in an innovative way. Alsayyar & Jrade, (2015) developed a model for the design stage of the building project, integrating sustainable universal design (SUD) principles with BIM Technology for the assessment of the cost and the benefit of alternative building solutions. The model outlines the following; "a list of the selected SU materials and components, their associated Leadership in Energy and Environmental Design (LEED) accreditation level; list of the associated universal design standards and suggestion; and a Lifecycle Cost Analysis (LCCA) report presented in the form of cash flow that is automatically generated" (Alsayyar and Jrade 2015).

3.6 Scandinavian Green BIM and United Kingdom Model

Scandinavian countries (Denmark, Sweden,, Norway and Finland) and United Kingdom (UK) are accredited as using Green BIM in its building projects system because of the investment that government has put in the model of technology for building projects (Araszkiewicz 2016). Adopting the approach by (Wong, WONG, and NADEEM 2013), this project will look at Green BIM Technology application from stakeholder's role in the Scandinavian countries and United Kingdom (UK).

3.6.1 DENMARK

Comparatively, in Scandinavia, According to Schwartz, (2014) and (Council 2016), Denmark is the most prominent user of Green BIM Technology because of its stringent specifications and standardisation guiding the Danish building industry. The Danish government has clearly laid down mandatory requirements for the use of BIM Technology in building projects since 2007. The key players in the Danish Architecture, Engineering, Construction (AEC) and Facility Management (FM) industry include the Defence Construction Service, the Danish University and Property Agency, the Palaces and Properties Agency. More importantly, without BIM Technology, a contractor cannot secure building contracts for government constructions. Apart from the government's active role in ensuring that BIM Technology becomes an industry practice, private companies like Rambøll and Co use 'bips' (a user driven organisation in the use of IT in the Danish construction industry) are also driving the BIM Technology adoption in Denmark through the use of the outcomes of the Digital Construction project. The Digital Construction project was a collaborative research program between the Construction Authority and the Danish Enterprise to

develop procedures for 3D CAD/ BIM applications for the use of the construction industry in the country. Furthermore, the Danish Universities are also participating fully in advancing knowledge on how BIM Technology can be successfully implemented. All public building projects in Denmark have to meet the Government demands for the use of information and communication technology Ministeriet for By, (2013) and Retsinformatik, (2013). The state of Green BIM Technology is highly developed in Denmark because of both the efforts of the government and the private sector.(Wong, WONG, and NADEEM 2013) Example of Office building constructed by the use of Green BIM concept in Copenhagen.

Fig.8. Gladsaxe Company House - Copenhagen Source: NCC

3.6.2 NORWAY

Norway is also using BIM Technology in its infrastructure development because of the involvement of key AEC/FM industry stakeholders and the state. The Norwegian Homebuilders Association and the private sector contractors like "Selvaag-Bluethink" are implementing research and results for the use of BIM technology in their building projects. Also, SINTEF as a research oriented institution has worked on more than 800 design sheets in a green building approach (Sunesen 2015), so as to integrates BIM Technology with Green building. The government is the coordinating organ for the BuildingSMART in Norway which brings the knowledge and expertise of stakeholders from the universities, the contractors association and collaborative organizations from several countries. Furthermore, the state through "Statsbygg" a civil client has developed the BIM Technology procedures called the BIM Manual.

Legally, since BIM Technology facilitates the sharing of information across different experts and companies, the Norwegian IAI Forum has taken upon itself to create a legal document to guide and specify how the information exchange process between the stakeholders using BIM Technology should be, for regulation purposes. This is the Information Delivery Manual (IDM) (Wong, WONG, and NADEEM 2013).

Fig. 9. KBS Shopping Center - Trondheim Source: Skanska

3.6.3 FINLAND

In Finland, many organization and the government are using BIM Technology and Green Building together in their Built Environment activities. One such organisation known as the VTT which studies building information modelling since 1980s. VTT plans to use green BIM Technology for its building projects. Also, "Tekes" has been encouraging the use of BIN Technology in Finland by pointing out its potential benefits for the Architecture, Engineering and Construction (AEC) and Facility Management (FM) industry.

Skanska Oy another Finnish company has been studying how to implement BIM Technology in its commercial building activities. A collaboration between the State represented by the Senate properties and the Association of Finnish Contractors have been in the area of open standards for BIM Technology use in the industry. The Senate Properties representing the government has been piloting certain Green BIM projects in Finland to check its feasibility and to come up with guiding standards and protocols for the industry.

Lastly, the universities and other research organizations have also been part in the BIM Technology by studying how it can practically be used in the built environment. The universities include Helsinki University of Technology and Tampere University of Technology (Wong, WONG, and NADEEM 2013).

Fig. 10. Manskun Rasti - Helsinki Source: Skanska

3.6.4 SWEDEN

Sweden has the same construction setting as of Denmark and Norway but is only their laws of operations that differ little bit as compare to their neighbour countries. One of leading construction Company in Sweden which is championing the use of Green BIM in its projects delivery system and management practices is Skanska.

Lindblad & Vass, (2015) conducted this research to investigate how the introduction BIM as Swedish public clients can bring organizational change in term of increase in performance and productivity on "BIM initiative projects". This research work is a direct response to Swedish government and Executive Board order from 2013, the decision is to encourage the use of BIM in all public projects in order to increase productivity in the construction industry. This BIM implementation affects both internal and external operations of the organisation and it goes a long way to serve as a foundation of development towards more use of BIM in the built environment. The studies period was five years, observed the BIM implementation within an Organization with semi-structured interviews to managers in-charge of BIM initiation projects. The researchers argue that, indeed, BIM Implementation in organization revolutionized work practices and processes, which in turns increased productivity but that is not enough. Established organization in construction industry must support the use of BIM in all operations, in order to ensure

quality technology and management. Nevertheless, certain structure need to put in place in respect to technology and organization re-engineering in order to effect these changes in the organization. The idea where the Swedish government supports and also playing active part in this BIM implementation in the field of procurement and construction of public projects is commendable.

Fig. 11. New Karolinska Solna - Solna Source: Skanska

3.6.5 UNITED KINGDOM (UK)

In the European construction market, The United Kingdom is documented as one of the leading countries in the BIM technology exploitation and this BIM technology has contributed immensely in both international and domestic markets for the growth of national economy (HM Government 2012). The United Kingdom (UK) Government is ambitious client, who has taken every opportunity to champion the use of BIM technology within its construction market. This BIM implementation Strategy Plan which was introduced in 2016, seek to transform and up-lift the image of the construction industry in UK. The Government intention is able to achieved 20 percent saving in its procurement cost. The Government also established BIM Task Group, having the responsible to help in BIM delivery and supply chain in reengineering the work practices for both private and public sector clients within the UK construction Industry (Smith 2014).

According to HM Government (2012), the reason behind this strategic move is as the result of the success the Government has accomplished on its domestic program on the use of BIM and the ambition to establish dominance in leadership role in BIM standard development, BIM exploitation and BIM service

provision. In the year 2010, the construction industry in UK recorded 2.5 million workers employed and £ 69 billion on Gross Value Added (GVA) was contributed the United Kingdom economy. These outcomes shows that through Government-led initiatives or impetus, the adoption of BIM technology in the daily execution of projects can yield positive results for all stakeholders as it is UK construction market.

Fig.12. New Papworth Hospital - Cambridge Source: Skanska

3.7 Green Building Design and BIM in Sub-Saharan Africa.

In search of Green BIM journals to be reviewed on the subject matter on the continent of Africa was limited. There are just few literatures that the researcher came across from Ghana and neighborhood country Nigeria. As a matter of fact, these materials are even written separately as the discussion of BIM and Green building design is concerned.

According to Abubakar, Ibrahim, Kado, Bala (2014), demonstrated in a survey to ascertain the level of BIM adoption awareness for contractors by sending out 100 questionnaires and having 49 in returned, the analysis response rate not lower than the range of 30-40%. The statement of argument was divided into two categories namely Drivers for BIM adoption such as availability of skilled professional to handle BIM tools, BIM software availability and affordability etc. and Barriers of BIM adoption in the Nigeria construction industry such as social and habitual resistance to change, contractual and legal constraints, high cost of integrated software for all professional in the AEC/FM industry. The findings show a potential market that is ready for exploitation but first, framework on education and training among all stakeholders must be established for the smoother BIM implementation in the Construction industry.

Ametepey, Aigbavboa, & Ansah, (2015), identified six essential factors; Management/Leadership, Political/Governmental, Financial, Knowledge/Awareness, Socio-Cultural, and Technical these sever as barriers to successful implementation to sustainable construction in the construction industry in Ghana. The adopted method by the researchers for the results the sustainable construction in Ghana by means of interviews – 18 Contractors, and 16 Consultants, whilst survey questionnaires was also given to 100 randomly chosen practitioners – 58 Architects, 37 Quantity Surveyors, and 5 Structural Engineers. The outcomes states that, implementation for sustainable construction in the Ghana requires Government partnering with stakeholders in the AEC/FM industry providing the roadmap for special legislation, sustainable codes and practices, creating the enable environment for research development on green design at the universities, professional groups like Ghana Green building council organizing seminars, workshops, and training on sustainable constructions. Its importance to modern day constructions and effects on society and the environment at large.

3.8 Summary on Literature Reviews

In summary, the analytical literature reviews on Green building and BIM technology on the various researchers do suggest that BIM and Green building concept can be integrated for construction works. The results of it impacts brings good returned of investment for Clients, and a healthy working environment for Architecture, Engineering, Construction and Facility management industry. Even though, some of literatures point to some risk related to BIM interoperability in Green building design, but is just a matter of the AEC/FM industry defining the format of tools to be used from the start of the project. Again, the awareness of Green building and BIM adoption with its implementation must be promoted in the developing countries like Ghana.

This study is the first to directly introduce the concept of Green BIM to the Sub-Saharan Africa country of Ghana. Since most literature discussed these concepts separately in the region.

In Europe, America and other part of the world, the promotion of BIM technology and Green building is welcomed and Governments are making legislation to support it operations in the Built Environment. There are companies in the fore mentioned countries that wins billions of dollars construction contracts in Africa. The question is, if steps are not taking to promote and transfer this Green BIM concept to the construction market in Africa, how could these companies function well? The world is now global village, adaption of Green building concept with BIM into the construction market in Ghana is a right research work as the literature reviews suggest.

It will help to improve the AEC/FM industry and will also sever as foundation for foreign construction companies wish to operate in the construction market in Africa with this Green BIM concept.

Chapter 4: Green Building Design

This chapter gives explanation to the term Green Building Design Concept, what constitute to Green Building practices and the best way possible to be used to achieve results within the built environment for Architects, Engineers, Contractors and Facility Managers.

4.1 History of Green Building Design and Construction

The history of green building can be traced way back the ancient Babylonians and Egyptians, where the indigenous people of the land used natural materials within their disposal to construct buildings in order to protects themselves against extreme temperature and wild animals (Kubba, 2012). As it in the "Our Common Future Report" called The Brundtland Commission (WCED 1987), defines sustainability as *"the ability to meet the needs of the present without compromising the ability of the future generations to meet their own needs"* However, in today's civilization, the green movement has different importance in the era of Industrial Revolution – mass production of building materials in faster pace with less cost and having the intent of conserve human labour. In the construction industry at this age, the use of modern technologies such ventilation, heating, air-conditioning (HVAC) systems are flourishing and are now part and parcel of building design considerations. These mentioned mechanical required energy to function well and it comes with cost (Krygiel and Nies 2008). In the year 1973, OPEC oil crisis that was erupted as been attributed to green movement, where there is need to diversified energy sources by way of opting for the use wind, solar, water and lastly, geothermal energy sources of power. The green movement global message of seeking eco-friendly solutions to the environment concerns was made strong because world leaders like President Bill Clinton, Chancellor Angela Merkel, Prime Minister Helen Clark and many more are outspoken advocators on the subject matter for the building industry and the built environment at large. (Kubba, 2012).

4.2 What is Green Building Design?

In the built environment, the term Green Building Design can be called in different names such as Sustainable design, Green architecture, Green design, Ecological design, but interestingly, its meaning is alike (McLennan, 2004). In the Architecture, Engineering, Construction, and Facility Management Industry the term green building is well known but it definition always come with a twist. In the context of this thesis report, the researcher will use the term Green building design or Sustainable design.

There are series of the different definition on green building or sustainable design the researcher has come across. According to McLennan, (2004) *"Green design is a design concept that optimize quality of the construction environment which in respect of reducing the negative effects to the natural environment"*

This definition by McLennan do emphasize that Green building is not a stylistic (aesthetic) endeavor but rather a concept or approach to design. The Building Services Research and Information Association (BSRIA) defines Sustainable construction as *"the ability to design and manage the construction environment by the use of recycle resources in an efficient manner as well as applying ecological principles"* (Tom Woolley, Sam Kimmins 2005) BSRIA has categorized ecological principles in three viewpoints, namely Reducing or eliminating the use of toxins, Non-renewable resource intake reduce, and Improving the natural environment.

In other viewpoint from industrial perspective of Green buildings definitions by the U.S Environmental Protection Agency (EPA) defines green building as *"the practice of creating structures and using processes that are environmentally conscious and the efficiency use of resources throughout a life cycle of the building's from siting to design, construction, operation, maintenance, renovation and demolition"* (Kubba, 2012).

In a nutshell, the researcher can therefore define green building as the respect and intentions one have to design the best construction solutions (aesthetics and quality), that provides comfort to the inhabitant, minimized the effects materials usage whilst acting environmental conscious on natural surroundings.

4.3 What constitute to Green Building practices?

The concept of Green Building practices is to design an artifacts that provides comfort and benefit to people whilst thinking positively to the natural environment in which this physical building is going to be constructed or built. Primarily, the main objectives of Green building concept is to design a building that will take advantage of the natural resources and geographic conditions such as water, sun, landscape, materials etc. in an efficient manner and subsequently, reduce the adverse effects on the environment and human health.

According to Kubba, (2012) .The components that made-up of Green Building practices are as follows; Land use (Siting), Energy Efficiency, Water Efficiency, Environmental air quality, Materials efficiency and resource conservation and last not the least is Building operation and maintenance.

- **Land Use (siting)** - Is the selection of the site to build on and capitalizing on the unique natural features of the land, for instance trees, landscape, which add value to the building design. Plants that are intended to be used must be carefully selected in order to add beauty to the surroundings.
- **Energy Efficiency** - The shape, size, position of a building can contribute to the amount of energy that building will utilized. In order to maximum energy efficiency and performance one needs to consider natural lighting and solar design in a broader perspective. In today's construction environment there are availability of even renewable energy sources that must be used in the design of any mechanical or electrical system within the building envelope.
- **Water Efficiency** - Water is necessity of life but the abuse of its use is costly. The other mechanism or strategies that one can adopt in order not to misuse water in the building is to deploying the use of low-flow showerheads and Ultra low-flush toilet to minimize wastewater. In some locality or areas self-closing hose nozzles are encourage to be used especially in schools or hospital buildings.
- **Environmental air quality** - One key element in life that prolongs the life of people is the kind of air quality people breathe in. Any building that lacks a good indoor air quality can results to all kind of respiratory diseases, asthma, allergy and so forth. Even though, good amount of ventilation is necessary, the materials used for construction and interior finishes materials should consist of zero emissions in order to enhanced the indoor air quality and this in turns increase productivity of employees.
- **Material Efficiency and Resource conservation** - There many ways in which one can adopt for the selection of materials and product for construction works. Some of factors that defines the material characteristics are high recyclability, low off-gassing of dangerous air emissions, longevity, zero toxicity, durability, reused content etc. This kind of decisions on materials selection encourage and promote sustainability within the built environment.

- **Building operation and maintenance** - Maintenance culture of any building prolongs it longevity and also perform to its utmost best level as intended. Green building before it commissioning must be tested for its functions like electrical, plumbing, mechanical and ventilation systems (Kubba, 2012)

4.4 Sustainability Development in Denmark

In Denmark, Sustainability development is transforming and growing very fast in the construction industry. In light of this thesis report, the researcher was granted an opportunity for an interviewed. The motive is to be familiars with the organization roles and operation with the Danish construction sector in respect to the development of green building concept in the construction market in Denmark. The Green Building Council Denmark (DGBC) is a non-profit governmental organization which was established in 2010. It has 250 members and the organization promote sustainability across the construction industry sector. The DGBC also organize sustainable courses for companies which wish to have DGNB certification system on new constructed buildings and more so, support the growth of sustainable buildings among stakeholders and ensuring for its stable development by achieving sustainable goals.

This search of knowledge is for the inspiration for the Ghanaian construction market players and to increase the level of ambition for sustainable construction in the Ghanaian construction market. However, the researcher aimed to implement the adaptation of Green BIM concept will tap into this innovation at DGBC as they adopted this system from Germany. The statistics obtained from the Denmark Green Building Council shows the growth sustainable development as be illustrated in the DGNB pre-certified buildings per year from 2012 to 2016 figure 13.

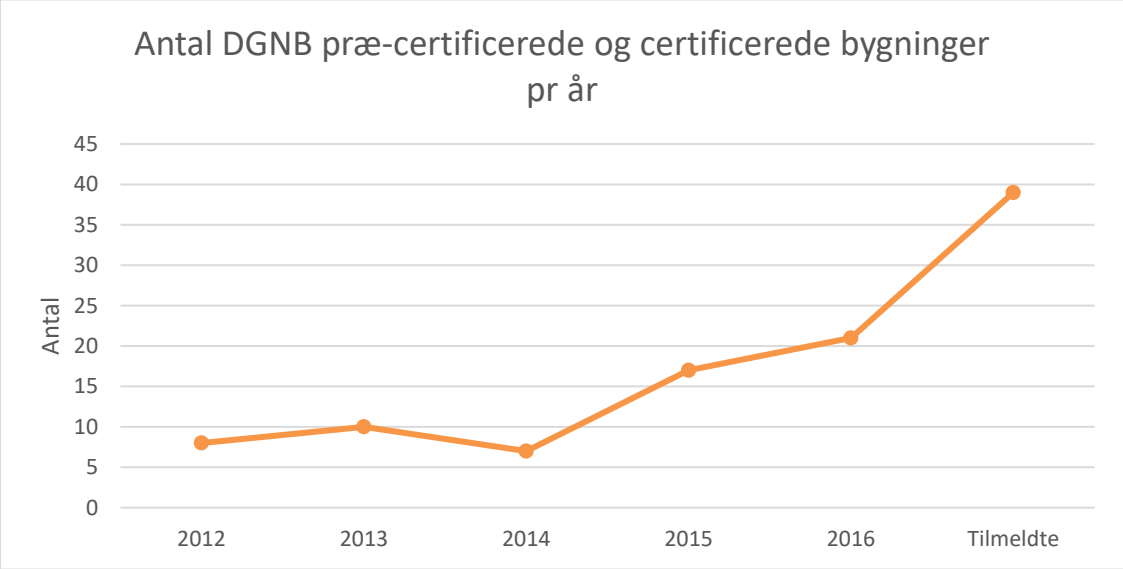


Fig.13. illustrated in the DGNB pre-certified buildings per year from 2012 to 2016

4.5 DGNB Certification in Denmark

DGNB certification system is similar to that of Leadership in Energy and Environment Design (LEED) system (US) and the Building Research Establishment Environmental Assessment Methods (BREEAM) system (UK). In 2012, the Denmark Green Building Council introduced this form of green certification system award to the Danish construction companies. DGBC adopted this DGNB system from Germany, which started using this award of certification system in their construction sector in 2008. The Denmark Green Building Council tailored this certification concept to suit the Danish construction environment and its legislation. The indicators on the graphic shows potentials and interest that this system is gaining in the Danish construction industry. The figure 14 shows the DGNB building certifications in Denmark from 2012 - 2016.

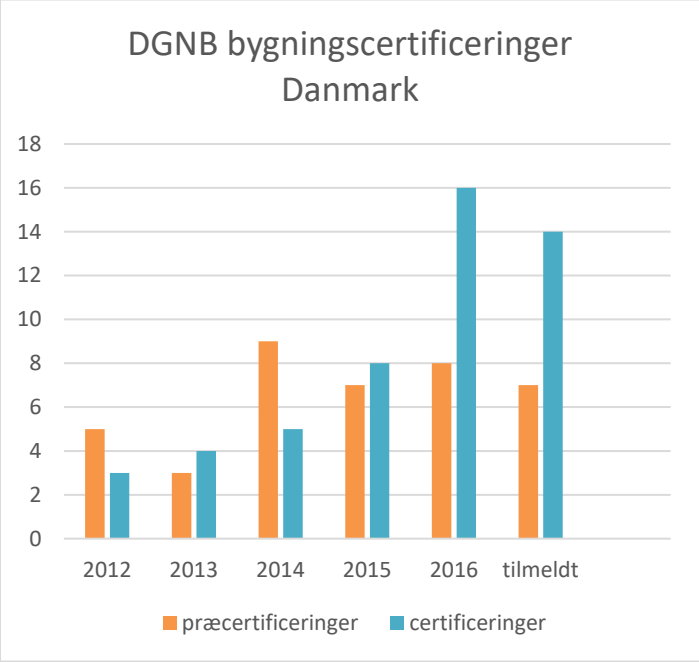


Fig. 14 DGNB building certifications in Denmark and measuring tool for sustainability Source: DGBC

According to Council (2016), the DGNB system of assessment of sustainability of buildings comes with 6 categories namely Economic Quality, Sociocultural and functional Quality, Technical Quality, Process Quality, Environmental Quality and Site Quality. Notwithstanding of these categories, there is 45 criteria used as parameter for measuring the sustainability in the life cycle of the building before award of DGNB certification award is issue.

Chapter 5: Building Information Modeling

This chapter describes what BIM technology can mean to Architects, Engineers, Contractors, Facility management industries and all the other stakeholders in general within the built environment. It also defines the roadmap on how to use it tools and the benefits it provides by helping to inform construction professionals the basis to execute construction project workflow to the complete lifecycle of a building.

5.1 Overview Building Information Modeling (BIM)

In today's built environment, the most buzz word that is trending in fields of architecture, engineering, construction and facility management industry is Building Information modeling (BIM). Although, there are a lot of documentations that shows how BIM technology has revolutionize the building industry when architects, engineers, contractors, and facility managers uses it to do their businesses. Inasmuch as BIM tool serves as vehicle to design and document of project data and most importantly, enhancing communication among project teams but yet not all construction professionals fully understand the fundamental behind its concepts. There is misconception that BIM is just only a software programs but the fact of the matter is that, the avenue it provides for project's stakeholders over exceeds just the term software (Krygiel and Nies 2008). One may ask then, what is the definition for term BIM? Building information modeling may have the widespread popularity in the built environment but failed to establish a consistency in its definition. These are series of definitions by some construction professionals and institutions, Patrick Suermann, of National Building Information Model Standard (NBIMS) says *"BIM is the virtual representation of the physical and functional characteristics of a facility from inception onward. It serves as a shared information repository for collaboration throughout a facility's life cycle"*. Again, in another twist, the National Institute of Building Sciences (NIBS) defines BIM as *"a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing earliest conception to demolition"* (Sam Kubba, 2012). More so, according to Krygiel & Nies, (2008) *"BIM is as the creation and use of coordinated. Consistent, computer information about a building project in design – parametric information used for design decision making, production of high-quality construction documents, prediction of building performance, cost estimating, and construction planning"*.

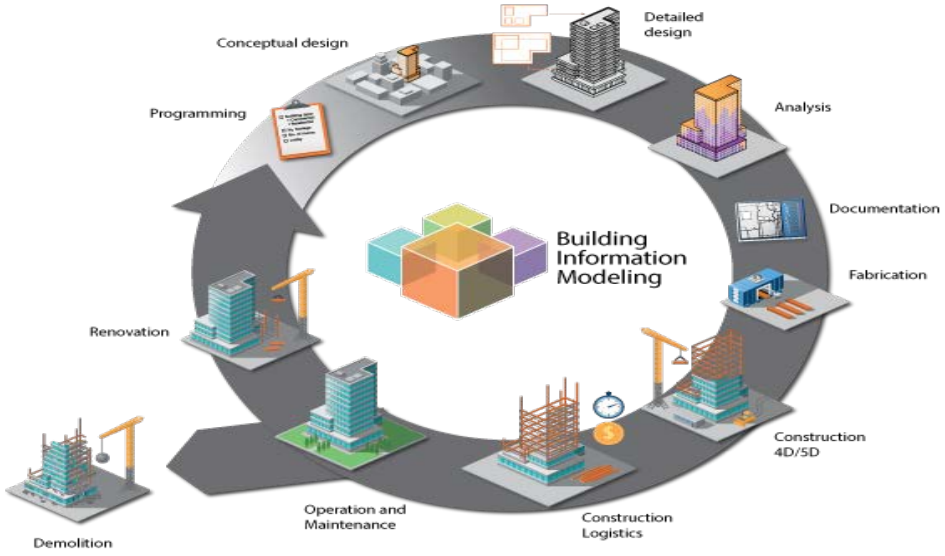


Fig.15 BIM Functions Source: Lloyd's Register

In the context of the different perspective of BIM definitions stated in this chapter, the researcher can therefore defined the term BIM as holistic methodological process with an aid of software's that consist of three-dimensional geometric model which is enrich with data. This data has the capabilities of forecasting project cost, energy consumption, scheduling, structural performance, estimation of quantity take-offs throughout the building life cycle. All stakeholders associated to the project can have access to the same information on the constructed model data, whether it be Architects, Engineers, Contractors, Facility managers, Building owners and so forth. The difference between the BIM-based system and the CAD-based system is that, BIM -based technology can construct complete digital virtual model which contains accurate and relevant data needed for fabrication and construction (Sam Kubba, 2012).

Eastman et al., (2011), identifies the following attributes and characteristics for 3D models that can be used to defined BIM - based system and the opposite is CAD - based system;

- Models without behavioral support - Models that does not contains parametric intelligence and lack the strength to adjust its positioning. This results for inaccuracy and inconsistency in the view of the model. Changes made on such works are time consuming and labour intensity.
- Models that does not have the capacity to updates its dimensions changes on one view to reflect to the others sides of model automatically - When these occurrence happens it degenerate to errors in the model and can be problematic to find it.
- Models that have only 3D data and without any object characteristics - This defines models that can have the ability for graphic visualization and does not contains object level of intelligence.

5.1.1 BIM numeric labels Dimensions

The following numeric labels defines it meaning in BIM technology and the functions it represent in the construction environment. (Kensek, 2014)

- 2D stands for two-dimensional drawings such as elevations, plans, sections
- 3D stands for 3D digital model, in addition of height measurement
- 4D stands for the integration of time with 3D, such as project schedule, construction sequencing and phasing
- 5D stands for addition of cost to the BIM model, meaning cost estimation during conceptual design phase or quantity take-offs for bidding
- 6D stands for life cycle, energy management components, and facilities
- 7D stands for life safety issues within the building e.g. building code analysis.

5.1.2 Origin of Building Information Modeling (BIM)

In the late 1970s, according to Aryani, Brahim, & Fathi, (2014), Professor Charles Eastman of Georgia Tech. School of Architecture initiated the Building Information Modeling (BIM) concept. The idea of BIM concept development is to enable stakeholders in the built environment to use it in various stages on project executions whether it be pre-construction stage, construction stage and post construction. At that time, Professor Eastman argument was that, drawings made for construction has limitation due to visualization of the buildings and also difficulty in updating drawings which goes a long way to affect efficiency in drawings production and quality. In light of this for mentioned observation by Eastman, ICT researcher and corporate organization from Finland and USA team-up to design and developed a comprehensive Computer software's capable to address the problems indicated in regards to project drawings and its management. In Figure 5.2, illustrate the development of BIM definition as computer program from 1975 to 2013.

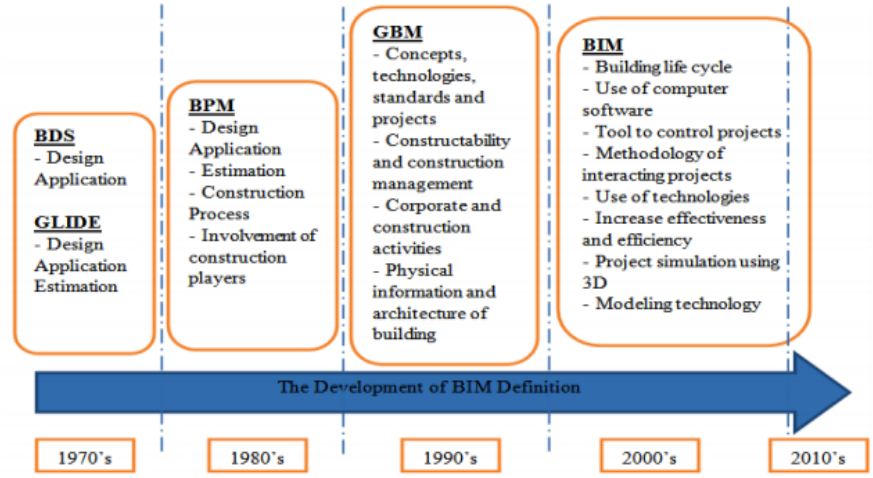


Fig. 16 Development of BIM Definition source: (Aryani, Brahim, and Fathi 2014)

- **BDS, 1975 - stands for Building Description System.** It function as database tool use in describing buildings during design and construction development. It has the capability to modify and operated numbers of element such as clashes detection design, analysis of cost from the individual database library.
- **GLIDE, 1977 - Graphical Language for Interactive Design.** It function as a tool that provides accuracy in evaluation of structural design and cost estimation. It mostly used in design stage only and it incorporated well with BDS parts.
- **BPM, 1989 - Building Product Model.** It provides the platform for construction stakeholders opportunities for to works on estimation, design application and construction process. This this innovation was made in Finland, is called "RATA" meaning Computer Aided Building Design. It functions as CAD (Computer Aided Design) interpretable communication tool. Again, it serve as project library which is enrich with projects information from planning stage to completion of construction.
- **GBM, 1995 - Generic Building Model.** The idea of Generic Building Model is to compensate the weakness that has been identified in the operation of GPM functions. It has the ability to improve and integrate project information from new design and future construction activities throughout the construction process life cycle. (Aryani, Brahim, and Fathi 2014)

Subsequently, Building information modeling has now become a solid spinal cord interlinking today's construction firms businesses and at the same time serving as an effective tool for information sharing and assessment of project data at different locations within the built environment for stakeholders. In the 1990, virtual enterprises concept was adopted to connect the fragmented stakeholders in construction industry to discuss and developed research mechanism framework to support and promote business models. Computer Integrated Construction (CIC) for instance, is a typical example of virtual enterprises uses to collaborate construction stakeholders together in the process of supply chain. In the mid-2000s in the USA, the term BIM was emerged and the CAD software manufactures came out with software's like Revit, Allplan and ArchiCAD etc. and these programs were used to promote the parametric modelling tool for Building Information modeling concept. The awareness of the BIM technology in the construction industry has created the following mindset and change of its understanding.

1. Increase: sustainability concept, infrastructure value, productivity, quality and information efficiency.
2. Reduce: building lifecycle costs, duplications of data and project schedule times. The ability to enhance communication and collaboration among stakeholders during construction project execution and the consistent reuse of digital information throughout the building lifecycle by stakeholders.

There has been earlier research on CIC, before the introduction of BIM and the outcomes is to find the best way to address ineffective cross-disciplinary communications challenges among stakeholders that hinder the progress and improvements in the construction performance in the industry. The very reason of Computer Integrated Construction (CIC) use is to permit different project stakeholders to make good use of project information on common platform by accessing and exchanging information digitally or electronically by the avenue of the project central database. In this system, communication between applications are efficient, knowledge on multiple application and multiple databases are accessible and integration through geometry enhances quality of work (Arayici, 2015)

5.2 BIM Integrated Information Model

In the platform of BIM technology, all project stakeholders on the construction project share a common information from the central BIM data source. This act fulfills the idea of BIM concept, where there is free flow of information and shared responsibilities among integrated project teams without any obstacles. Whilst in the traditional team model, information flows from the building Owner to the Architects and

then spread to the various individuals or trades undertaken the proposed project. This has the tendency to have communication problems among project teams and it can ends up affecting the overall execution of the project results. Within the BIM platform, some of the activities that integrated teams engaged in are Modifying, extracting, collaborating, updating and inserting other relevant information to the constructed model database. The results of the integration of project teams on common database minimize cost, errors, time, and promote the quality of project works.

Figure 5.3 illustrate how the BIM process mode look like as compare to the traditional model that has been in use in the construction industry for many years ago.

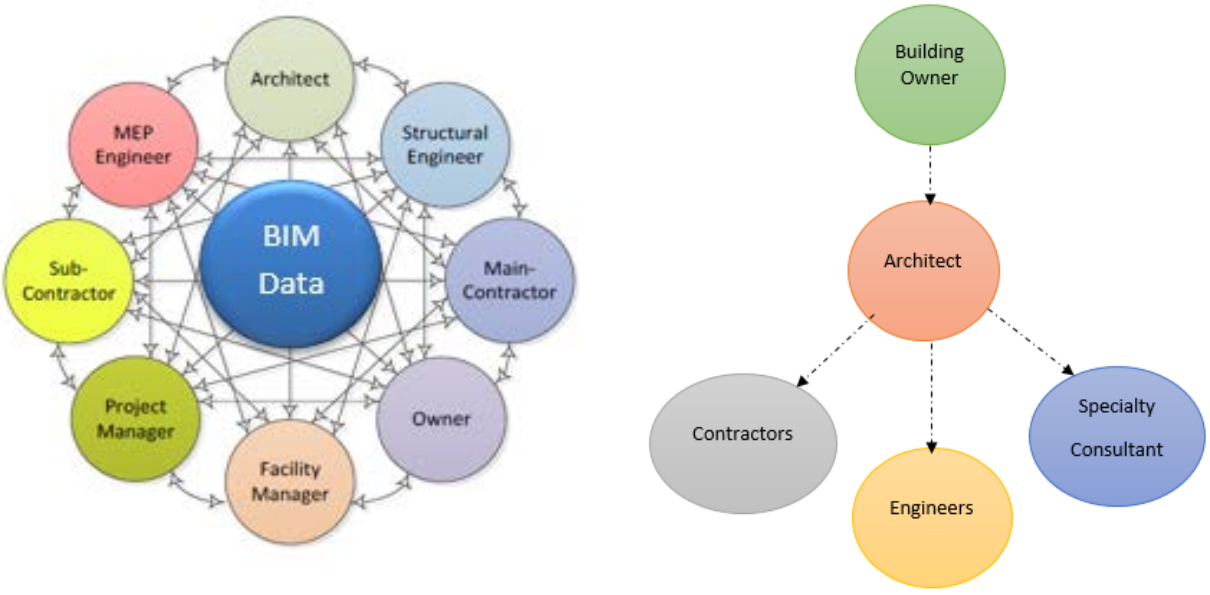


Fig. 17. BIM information model vs traditional source: Aðalsteinsson, (2014) and Krygiel & Nies, (2008)

5.2 BIM Data Exchange and interoperability

One of the most effective tool associated with BIM technology concept is the ability for data exchange between various project stakeholders such as the building owner, architects, contractors, facility managers is interoperability. The term interoperability is defines as the means in which a project data is transfer to different domains and applications electronically for the use the project stakeholders. (Karen M. Kensek, 2014).

According to (Eastman et al. 2011), interoperability *"is the ability to pass data between applications and for multiple applications to jointly contribute to the work at hand".* Some years ago, file-based exchange formats for instance DXF (Drawing eXchange Format) and the only exchange geometry file IGES (Initial Graphic Exchange Specification) are used to transfer 2D and 3D drawing data between different CAD systems. In this interoperability, manual copying of project data results to errors and this goes a long run to create inconsistency in cumulated data in automation. With BIM Technology, constructed model carries more integrated information as compare to CAD files. Interoperability most challenges is exchanging data on design platform software like ArchiCAD, Digital project, Revit on platform - to - platform exchange. The reason for this problem is that one has to manage and take control of all the multiple representation on the assigned project at the interoperability platform at tool levels.

5.3 Building Information Modeling (BIM) Stages

According to Succar, (2009) there are three stages before BIM implementation can be initiated. However, there is also the need for the built environment stakeholders should be conscious to understand the principles of these stages. This information will be much appreciated when the researcher is outlining the roadmap and strategy for adopting Green BIM concept in Ghana in chapter 9.

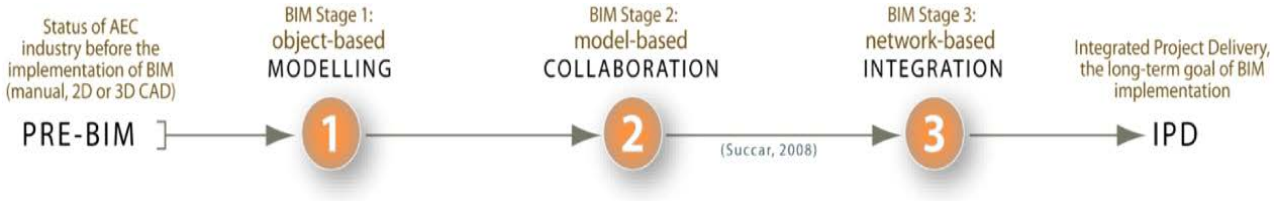


Fig.18. Illustrate linear view of BIM maturity Source : adapted from (Succar 2009)

5.3.1 BIM Stage 1 - "*Object -Based Modeling Synopsis*"

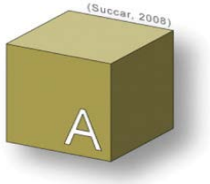


Fig. 19. Image of single disciplinary model

In this stage, Architects, Engineers, Contractors and Facility managers' uses object based 3D software technology such as Autodesk Revit, ArchiCAD and Tekla to create or design a constructed virtual model which in turns is generated by a single - disciplinary models in the project lifecycle phases (Design, Construction and Operation). It's basically used to create deliverables like 3D visualization, drawings, documents, and schedules which are coordinated with the constructed BIM model.

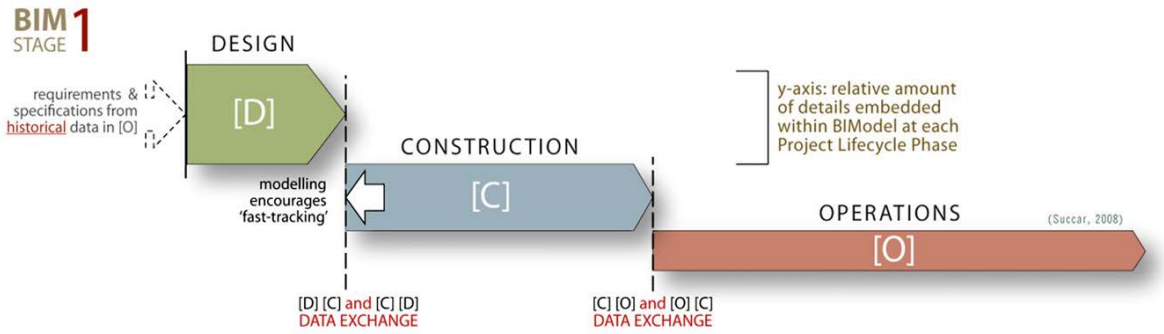


Fig.20. BIM Stage 1 of project phases Source : adapted from (Succar 2009)

5.3.2 BIM Stage 2 - "*model - based collaboration synopsis*"

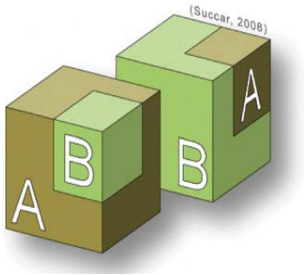
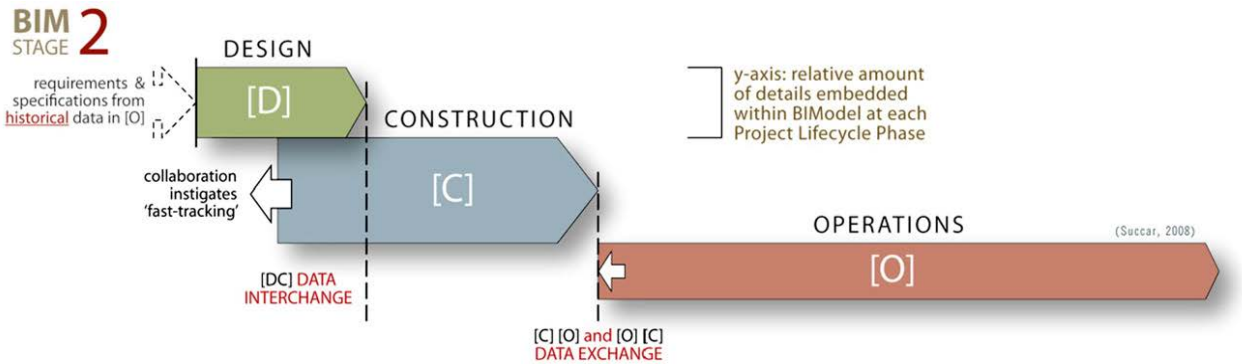


Fig. 21. Illustration of single disciplinary model with 2D BIM integration tool

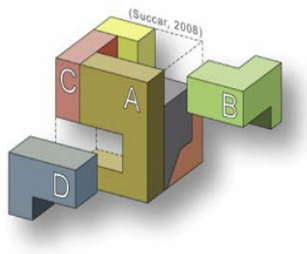
In Stage 2, construction players works in collaboration with each other stakeholders by ensuring each actors choice of BIM technology tools to be used. There are two model-based collaboration namely Part-models by used of proprietary formats or interchange of models, for instance, Autodesk Revit Architecture and Revit structure via proprietary file format .RVT, and the non-proprietary formats, the used of IFC file format for Tekla and ArchiCAD software. In BIM process stage 2, within the project lifecycle phases, the Model-based collaboration can be in either the Design -Design interchange (DD) or Design Construction interchange (DC) and it must not be more than two. Another vital information that is worth to note is that, only one of this collaborating model can contains the 3D geometric data which in turns permit for semantic between two disciplines. For instance, scheduling database by the use of MS project or Primavera, cost estimation on Timberline or Rawlinson's. It possible to work on these interchanges on time analysis (4D) and cost estimating (5D). The reason for this procedures is to establish communication consistency and workflow for construction players.



(Succar 2009)

Fig.22. BIM Stage 2 of project phases Source : adapted from (Succar 2009)

5.3.3 BIM Stage 3 - *"Network - Based Integration synopsis"*



In Stage 3, the creation of semantically-rich integrated model is generated, shared and maintained for all project teams across project life - cycle phases as illustrated in figure 23.

Fig.23. integrated model with multiple disciplines on single model

The collaboration and integration process in stage 3 can be achieved then there is the need for model sever technology that have the capability for proprietary or non - proprietary formats on single integrated or distributed database. It is in only BIM stage 3 that complex analysis can be performed at the early stage of virtual model design and construction due to the interdisciplinary "nD" models. Moreover, model deliverables can be extended to semantic object functions or properties such as green policies, lean construction principles and the whole lifecycle costing. Additionally, in perspective of process, project Lifecycle phases do overlap lengthily due to synchronous interchange of model and document-based data. The network -based integration causes simultaneous construction that leads to an Integrated project Delivery.

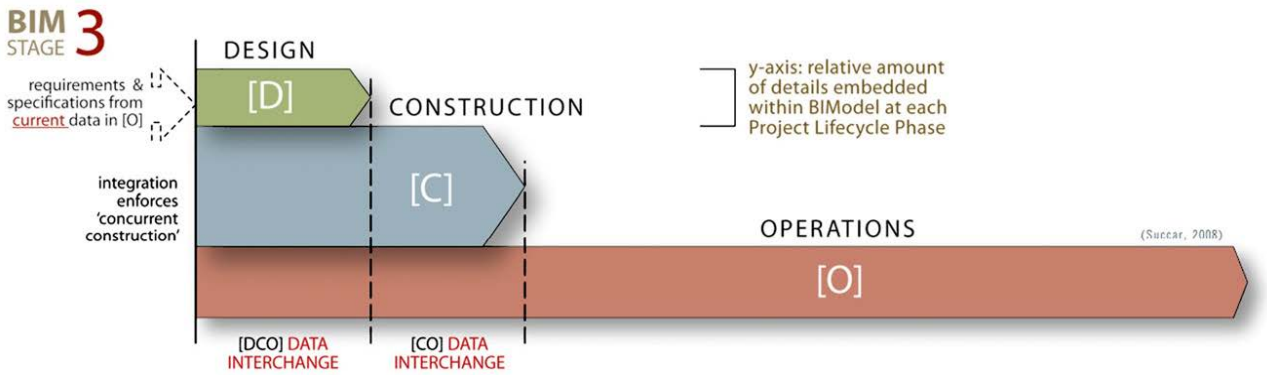


Fig.24. BIM Stage 3 of project phases Source : adapted from (Succar 2009)

Chapter 6: Analysis of Data and Discussion

In this chapter, all the analysis is based on the data collected from the various respondents and the interviews conducted by the use of Mixed Methods Research. The researcher match is assessment and findings in respect to the research questions in chapter 1. Other equally important materials which due to space and clarity has be documented in the ***Appendix A-D*** *for this thesis report.*

In reflection to the aforementioned thesis objectives, this research work specifically seeks to address the following questions in respect to adaptation of Green Building Design concept with BIM into a new construction market - Ghana.

Primary Research Question:

1. **How to adapt and implement Green BIM concept into the construction market in Ghana in the AEC/FM industry?**

6.1 Background of Respondents

The background of Respondents defines; who do the researcher interviewed? Whom answered the survey? What is their status in the construction sector? What is their level of education? And How long have they worked in Ghanaian construction market? In figure 25, summaries the survey contributor's characteristics as provided in the questionnaires data.

Variable	Categories	Frequency	Percentage
Professional Background			
	Architect	10	42%
	Engineer	4	17%
	Contractor	5	21%
	Facility Manager	1	4%
	Project Manager	2	8%
	Others	3	13%
Total		25	100%
Years of working Experience (Years)	0-5	12	52%
	6-10	7	30%
	11-15	3	13%
	16-20	0	0%
	Over 20	1	4%
Total		23	100%
Working Place			
	Architectural Firm	7	30%
	Real Estate Developer	3	13%
	General Contractors	8	35%
	Owner-Builders	3	13%
	Engineering Firm	2	9%
	Others	1	4%
Total		24	100%
Educational level			
	Post Graduate	11	48%
	First Degree	8	35%
	Higher National Diploma (HND)	2	9%
	Construction Technician Certificate	2	9%
	Others	0	0%
Total		23	100%

Fig. 25. Background of survey respondents (See Appendix A)

From the figure 25 above, majority of the respondents were Architects representing 42% of the total population of those who responded, followed by Contractors making up 21% and Engineers with 17%. The other professions represented include Project Managers (8%), Facility Managers (4%) and those with other careers representing 13%. From the results, it can be observed that the respondents are representative of the Architecture, Engineering, Construction, and Facility Management Industry (AEC/FM Industry) in Ghana and will have the requisite knowledge to answer the questions being asked. This sets the study in the right direction. Furthermore, project managers, architects, engineers, contractors, facility managers who responded are knowledgeable in the issues in the AEC/FM Industry in Ghana.

Also, another interesting finding emerging from the study is the number of working experience contrasted with the educational level of the respondents. Even though, more than half of the respondents representing 52% who indicated that they had up to 5 years of experience within the industry, almost the same number of respondents (48%) had a post graduate education, meaning that although the level of experience is low, the intellectual capacity and sectoral knowledge of the respondents is high. This shows that the low level of experience will not have a significant impact on their appreciation of the issues being discussed in this study. In addition, those with 11 years or more accumulated experience in the respective professions represent 17% which will allow for varied perspectives in the answering of the questions to present a holistic account of the Architecture, Engineering, Construction, and Facility Management Industry in Ghana. An explanation for the low levels of experience of respondents might be explained by the fact that Green BIM as a new concept in the industry is more likely to be exposed to the younger highly educated professionals in Ghana than the more experienced conventional workers who might not be keeping up with new trends in the industry. This might account for the low levels of experience.

With respect to the organizations that the respondents worked in the distribution were 35% for General Contractor companies, 30% for Architectural Firms, 13% for Real Estate Organizations and Owner-Builder Companies, 9% for Engineering Firms. A negligent percentage (4%) represented those in other kinds of organizations.

From the results above, it can be established that the Contractors and architectural companies are in the majority which is similar to the findings of Ampadu-asiamah & Ampadu-asiamah, (2013) indicating that in Ghana, the industry is dominated by the general contractor and architectural firms.

6.2 Stakeholders attitude and perception on Green BIM

Q1. Are stakeholders open to adopt the Green BIM philosophy and what are their perception of it uses on execution of new projects management in the construction industry in Ghana?

The first question of the study was focused on the attitude and perception of stakeholders in the construction industry in Ghana for the use of Green BIM. To answer this question, the study asked respondents two sub questions one related to Green building and the other one on BIM Technology. Below is a description of the findings.

A. Stakeholder attitude and perception towards Green Building

. A summary of the response indicating the high and very high responses is presented in the figure 26, below with a more detailed representation in the Appendix A. The summarized response provides a clear indication of the perception and understanding of the majority of the respondents on the adoption of Green building in the Architecture, Engineering, Construction, and Facility Management Industry in Ghana. When the respondents were asked the extent to which they understood the Green Building concept, 59% indicated that they highly understood the concept. Secondly, when asked whether they would support governmental legislations concerning the use of Green Building practices in the industry, a greater number of the respondents (72%) specified that they would support such an initiative. Still on the perceptions of stakeholders towards the use Green building concept in Ghana, 86% of the respondents answered that they believed the adoption of the practices of Green building in their organizations will be beneficial. Lastly, in a bid to explore the attitude of the respondents towards climate change issues and sustainability, respondents were asked about how they viewed the likelihood that the use of Green building designs for construction purposes in Ghana will lead to a reduction in the threats of carbon emission as well as to promote sustainability for future generations. The recorded answers showed that 95% agreed with the statement with only 5% disagreeing with

the statement. In general, what can be observed from the findings in this section of the questionnaire is that, stakeholders and industry players in Ghana have a positive perception and attitude towards the use and implementation of Green building practices in the Ghanaian Architecture, Engineering, Construction, and Facility Management Industry and are willing to welcome such an initiative. With such a positive response, the implementation of Green building practices in Ghana will be relatively easy since stakeholders' are both supportive of the idea and have high interest for the concept.

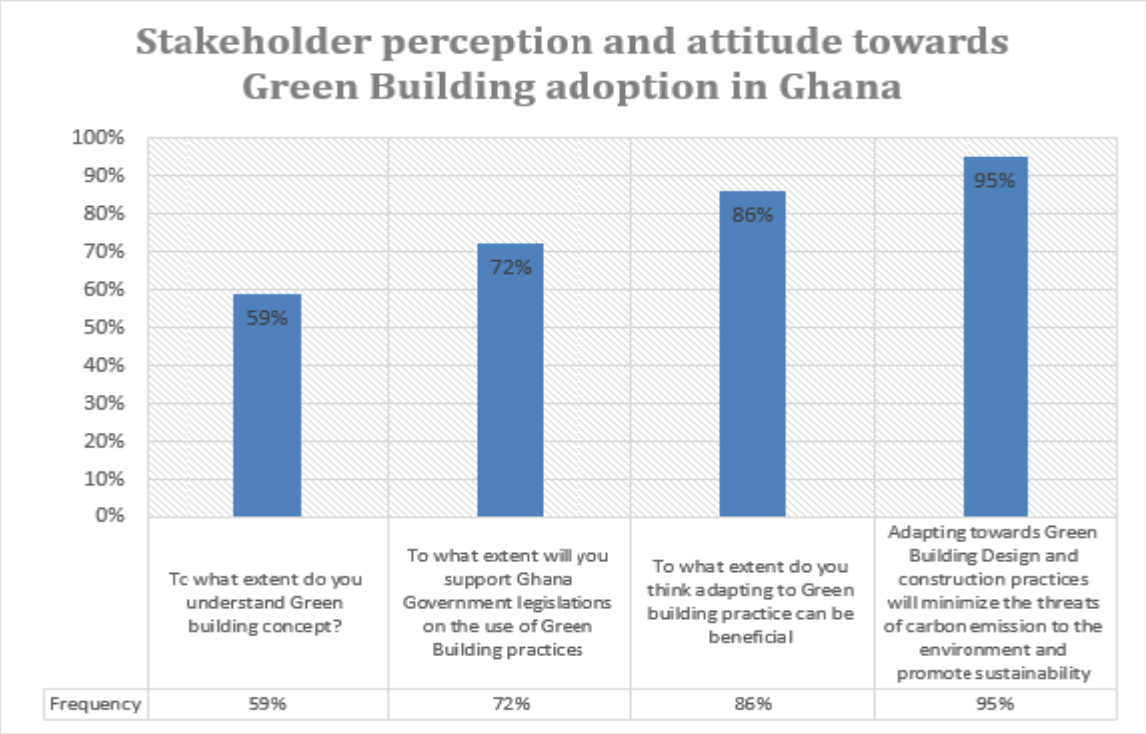


Fig.26. Illustrate Green Building perceptions of Stakeholders

B. Stakeholder perception on BIM Technology

Figure 6.3: To what extent will you promote the adaptation and implementation of BIM technology into the construction market in Ghana? (See Appendix A.)

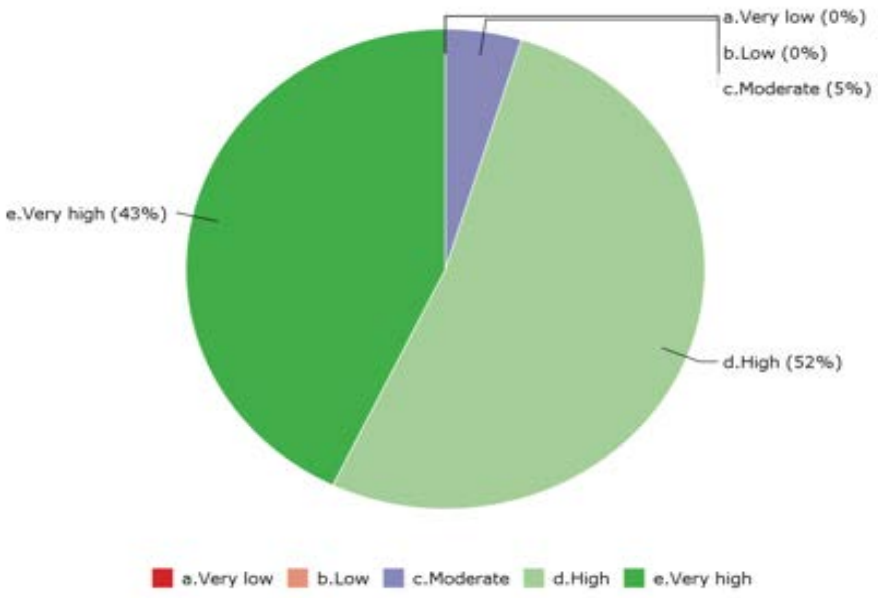


Fig. 27. Interest of BIM implementation by stakeholders

The outcome of survey concludes that majority (52%) of the stakeholders in the construction industry in Ghana do welcome the BIM technology concept. As in the western world, government is one of the key pillars that champions the use of BIM technology by making laws and regulations to promote and enforce it. In view of that, the Ghanaian government has an essential role to play to promote the use of BIM technology in the built environment in Ghana. However, other professional bodies could also organize programs in universities and other key influential industry players could join the crusade in disseminating the benefits and advantages of the use of BIM technology. What is therefore, needed to make the implementation of BIM technology in Ghana a reality is the institutional framework because there is the need for supportive systems and structures.

Figure 28: BIM adoption enhances the achievement of sustainable objectives in construction management, which application of BIM software have you worked with in your company?

(See Appendix A)

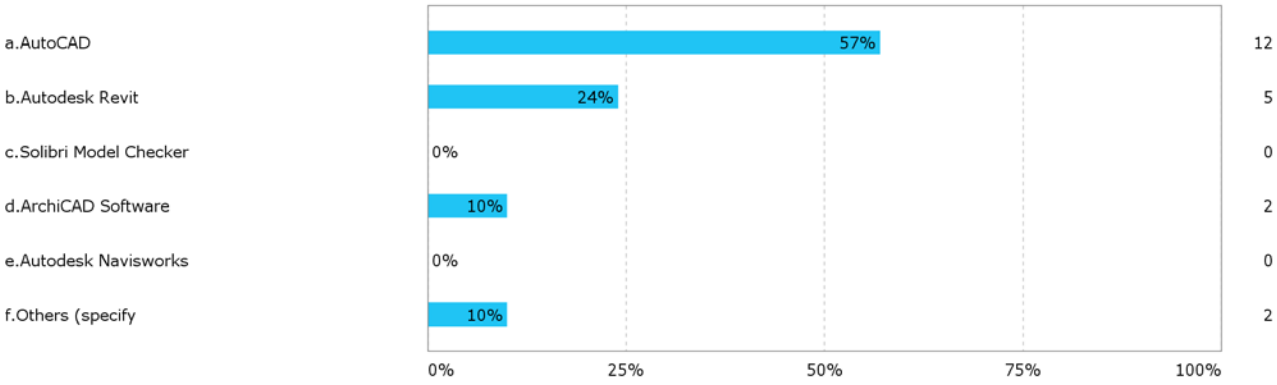


Fig. 28. BIM software use in the construction

In addition to the above results, the respondents indicated that they used BIM software like AutoCAD (57%), and Autodesk Revit (24%). The two software as shown in figure 28, are the most common BIM software tools used in the Ghana construction industry according to the survey. This indicates that the built environment has some existing infrastructures that need to be upgraded to the western standard.

6.3 Stakeholders Power/Interest Matrix Analysis

The Stakeholders power/interest Matrix is a tool used to identified key players on an industry in which one want to tap their influence and investment on given product. In the case of this thesis report, stakeholders' contribution are one of key pillars in implementing the Green BIM concept in the Ghanaian construction market. The ability to identify them gives you the platform to engage them for the success of the project. However, failure to recognize their influence in the industry set-up will result to delays or the tendency of failure for the Green BIM implementation process take - off.

The analysis of these stakeholders gives the researcher the leverage to target them as the engineer of the take-off for the implementation of the Green BIM concept. The analysis in figure 6.5, divides the stakeholders for this report into four (4) segments. The list below are the breakdown of the stakeholders.

1. Government
2. Architects
3. Engineers
4. Contractors
5. Facility Management
6. Software Vendors
7. Owners/Clients
8. Project Managers
9. Labours
10. Sub-contractor
11. Computer Engineers
12. Top Managers
13. Suppliers
14. Education Institution
15. Project Sponsors
16. Administrative supports
17. Project Teams
18. Research Group

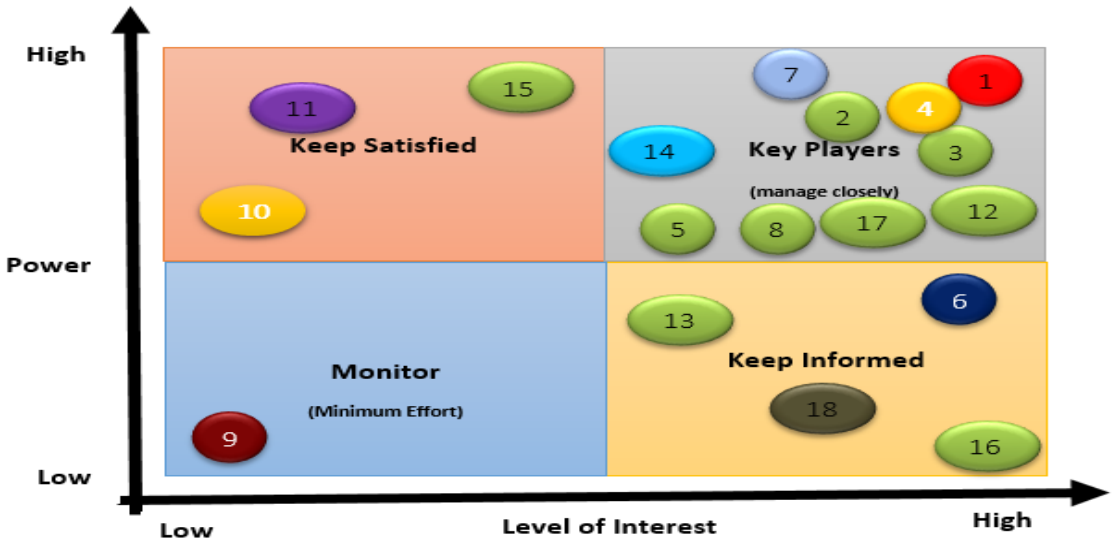


Fig. 29. Stakeholders Power/interest Matrix

- **Key Players - High power, high interested:** This defines stakeholders you must fully engage with, and make the greatest efforts to satisfy.
- **Keep Satisfied - High power, low interested:** put enough work in with these people to keep them satisfied, but not so much that they become bored with the product
- **Keep Informed - Low power, high interested:** keep these stakeholders adequately informed, and engage them to ensure that no major issues are arising. These players can often be very helpful with the detail of your project.
- **Monitor - Low power, low interested:** These stakeholders have low power and interest but cannot be sidelined, monitor these players, but do not bore them with excessive communication.

Summary:

The findings of the stakeholder's interest of Green BIM concept implementation into the Ghanaian Construction industry is very positive and encouraging. The respondents do welcome this innovative technology and have the conviction that this will bring some kind of efficiency and effectiveness into the construction market in Ghana. The idea of promoting sustainability in the construction sector will yield higher percentage in environmental consciousness and also transforming the landscape of the nation building infrastructures. The most important concern was, the Government should take proactive steps

to make policies and legislations that enforced the use of Green BIM concept in order of achieving sustainable construction sector with near zero emission.

Q2. How will Green BIM improves project management team's collaboration, efficiency in information sharing, project scheduling and project delivery system for AEC/FM industry in Ghana?

As it has been stated at the beginning of the study in the initial problem statement, the construction industry in Ghana has been bedeviled with a number of challenges and issues which has negatively affected the success of the project execution in the built environment. This study specifically focused its attention on the issues related to inefficiencies in relation to organizational management and the deficiencies in technological upgrades for effective operational process or methods within the Ghanaian construction industry.

In line with this objective, respondents were asked to identify the major problems affecting project management and operational processes within their firms in the execution of their duties as construction professionals. The answers ranged from lack of analysis tool for the design building model (3D), difficulties in collaborating with other companies on project execution, finances, political interference, lack of managerial understanding of project management, lack of good data documentation on project, management of 2D Drawings, the use of CAD software's for building design, low levels of understanding of BIM process and lack of advance technology.

A close look at the responses, shows that the most important problem area affecting project management and operational processes for the respondents was the lack of analysis tool for the design building model (3D) representing 45% of the responses. The second challenge high on the list indicated by the respondents with a score of 36% was improper data documentation of projects.

Thirdly, another problem identified in project management in Ghana was the difficulties that stakeholders experienced in collaborating with other companies on project execution. According to the findings, collaboration challenges across companies affected the successful execution of projection management and organizational processes. The fourth most important challenge, Management of 2D drawings was another area of concern with 23% of the responses. Finally, the respondents expressed their challenge with the use of CAD software's for building designs making it the fifth major challenge at 23% when it

comes to project management and organizational processes within Ghanaian firms who operate in the construction industry.

The findings of this study, is in line with Laryea, (2010) who also found out that within the Ghanaian industry, lack of qualified construction professional with the technical know-how in project management and execution, improper documentation causing design problems and inadequate funds were some of the prominent factors affecting the stakeholders in their day to day execution of their duties. This shows that since 2010, the challenges within the Ghanaian Architecture, Engineering, Construction, and Facility Management Industry has still not been addressed making it important to find ways and steps to address these challenges. Unlike the previous research, the current research takes this further by not just identifying the problems but suggesting solutions through the best practices identified in the Scandinavian and United Kingdom construction industry. In the Danish industry, the best practice is using Green BIM concept in the construction industry and the Government had made laws in support of its operations, when this implemented in Ghana will solve the above problems that have been identified in the studies.

6.4 Construction Style Analysis

The current construction practices in the Ghanaian construction industry is traditional or conventional style of building, based on the data received through the questionnaires survey and the interview conducted by the researcher with some construction industry players in Ghana (See Appendix A & C). The idea of using Macleamy Curve (Fig. 30) to illustrate the difference between the traditional style of building and the BIM process, is for one to appreciate and comprehend cost benefits and the degree of decision making effects on project from the beginning.

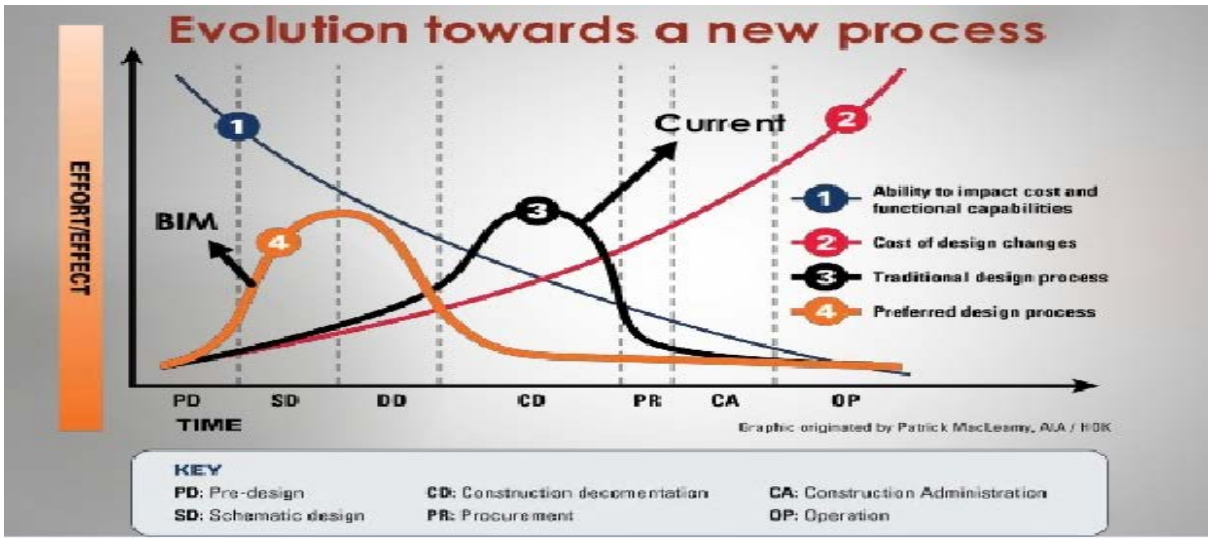


Fig. 30. Illustration of the Macleamy curve, BIM process vs Traditional design (Serginson, Mokhtar, and Kelly 2013)

Traditional Design Process ("3"-Current) - Basically, the project starts from the pre-design phase with less decision making process , small team as design, and with little effort. But as the project design advances or progresses with time through design development there is an increase in design team and efforts, during the construction phase. The problem with this design process is that any unforeseen changes that occurs in the middle or late of project execution comes with more cost and more time consuming by trying to rectifying the problems either in documents or construction works. Sometimes, this problems leads to construction litigations which the design team is powerless, is up to the lawyers and judges to handle it.

BIM Design Process ("4" - BuildingSMART) - This is the new strategy of building where higher number of design teams invest more efforts (decision making) into the development and testing of design alternatives at beginning of pre-design phase. The documentation of all the information given by the project teams are used to create the three-dimensional BIM model which enhances smooth working process. The project cost is manageable or controllable in the early stage of the project execution and the likelihood for multiple errors is avoidable. The good side of this system of construction is that there is better collaboration and coordination among project teams which helps a lot to eliminate any litigation which sometimes do occur in construction projects.

Summary:

All the problems identified which is related to organizational management and operational process is due to poor technological tools and Human relation management except Finances. The days of traditional style of design process or building is has come to end especially in Denmark and Europe in general. This findings goes to say that, any company or nation who wish to compete in the global construction market must invest in innovative technology like BIM and also develop the human resource capital. Today's technology goes along with human competencies and in turns yields higher productivity which brings good returned of investment for the company's business or boast growth the nation's Gross Domestic product (GDP). The proposal of Green BIM concept can address all fore mentioned main problems as stated in sub-chapter 6.7. the illustration of Macleamy Curve shows in figure 30 shows the avenue in which BIM technology implementation can offer to the Ghanaian construction industry most especially for the works of Architects, Engineers, Contractors, Facility managers and so forth. This same tools can used to perform all kind of analysis and building model stimulations within the built environment.

Q3. What are the barriers for the success of Green BIM concept adoption and implementation for the AEC/FM industry in Ghana?

One of the major motivation for the study was based on the fact that even though, the concept of Green Building Design with Building Information Modeling (BIM) technology has been used in many projects within the built environment in the western world this has not been the case in Ghana which has been slow to adopt the concept with only one documented building in the whole of the country called One Airport Square (Partners et al. 2013) using this concept. The inability of the Ghanaian AEC/FM industry to adopt Green BIM can be attributed to certain barriers and challenges. The current chapter will explore the barriers that are preventing the successful implementation and adoption of Green BIM concept for the AEC/FM industry in Ghana.

In exploring the barriers for Green BIM adoption and application in Ghana, respondents were given a list of factors which they ranked from no challenge to very critical challenge. Below is a tabulation of the results ***In Figure 31: Barriers for the success of Green BIM concept adoption and implementation for the AEC/FM industry in Ghana***

	No challenge	Less challenge	Neutral challenge	Critical challenge	Very critical challenge	Total of Critical + very critical challenge
Investment cost (equipment, infrastructure,) in BIM technologies	0%	10%	33%	29%	29%	58%
lack of standardization of practices	5%	0%	33%	48%	14%	62%
Poor collaboration with other professionals	5%	19%	33%	29%	14%	43%
Lack of information management standard practice	0%	10%	29%	52%	10%	62%
Lack of professional with BIM knowledge	5%	19%	14%	24%	38%	62%
High initial cost in education (Financial Resources)	0%	24%	24%	48%	5%	53%
Poor technological edge in the construction industry	5%	14%	29%	38%	14%	52%
Existing construction culture against current innovation practices	0%	14%	19%	38%	29%	67%
No laws enforcement on green building concept in all projects	10%	14%	24%	24%	29%	53%

Fig. 31. Illustration of list of BIM adoption barriers in the Ghanaian construction. (See Appendix A)

The above figure 31, clearly indicates the challenges that serve as a barrier for the adoption and use of Green Building concept with BIM technology in Ghana, the responses recorded for "critical challenge" and "very critical challenge" were combined together because it has similar meanings.

These figures will be used for the consequent discussion that follows and will be referred to as critical challenges. Except for "Poor collaboration with other professionals" which had a score of 43% as a critical challenge, all the other barriers identified had a score of more than 50% as critical challenges. The main critical challenge discovered from the analysis of findings presented in the figure 31 was related to the existing construction culture which was against current innovation practices. Cultural environment has always been a major driver or barrier to the implementation of new ideas within any construction industry and that is why Dowsett & Harty, (n.d.) emphasized that it is important that the cultural environment is not neglected in the implementation of BIM and sustainable designs. The fact that most of the respondents were of the view that the construction culture in Ghana which does not encourage innovation as the key critical challenge that would prevent the implementation of Green BIM concept is a confirmation of what has already been observed.

Apart from the cultural challenge, lack of standardization of practices, Lack of information management standard practice and lack of professional with BIM knowledge with a rate of 62% were also some of the important barriers that stakeholders acknowledged. Whilst the lack of standardization of practices and lack of information management standard practice relates to the level of industrial protocols, structures and policies in Ghana, the lack of professional with BIM knowledge are related to human capital challenges. Other of critical challenges include Investment cost (equipment, infrastructure,) in BIM technologies with 58%, High initial cost in education (Financial Resources) and No legal enforcement on green building concept in all projects (53%).

At 52% "poor technological edge in the construction industry" was also part of the critical challenges that was distinguished as a barrier for the adoption and use of Green Building concept with BIM technology in Ghana. According to a report by International Telecommunication Union (ITU) in 2015, (ITU, 2015) the level of technological development in Ghana is low with 23.5% of Ghanaians using the internet therefore the finding that there is poor technological levels in the construction industry in Ghana is not a surprise. This is a significant challenge that is a barrier for the implementation of Green Building concept with BIM technology in Ghana.

6.5 Technology Analysis

The technology analysis will seek to evaluate current state of technological tools deployed in the construction market in Ghana. Does these tools on the basis of data collected match - up to the standards

as compare to Denmark and Europe in general. Again, is this tools equip enough to provide a strong foundation for BIM process in terms of providing efficiency and effectiveness to construction management?

In reflection to the thesis data collected both in the survey and interviews, the researcher observed technological deficiencies in the Ghanaian construction market and especially software programs for Design, Project scheduling, Project cost estimation, Energy usage analysis (see Appendix A) as compare to what the Researcher witnessed at Rambøll A/S, Aalborg -Denmark. The interviewed conducted at Rambøll AS, enlighten the researcher understand on the importance of software programs which will enable one to achieve its project target and bring efficiency to project delivery. The opportunity given to see some programs as it functions and an oversight of the series of software used on their projects in Denmark. In figure 31 is just selected software programs used at Rambøll A/S, Aalborg and the overall oversight for CAD programs of Rambøll A/S is documented in Appendix B.

AutoCAD	Bentley Architecture	Solibri model viewer
AutoCAD Map 3D	Bentley Structural	Solibri model checker
Autodesk 3ds Max	Bentley MAP	AutoCAD Raster Design
Autodesk Inventor	Bentley View	AutoCAD Architecture
Autodesk Revit	Vico Software	ProjectWise Explorer
AutoPIPE Plus	Tekla	Navisworks
Bentley AECOsim	SolidWorks	ProSteel 3D

Fig. 32. Oversight of some selected CAD software at Rambøll A/S - Aalborg (see Appendix B)

Summary:

The findings of the researcher analysis has indicates there are some barriers which can be an obstacle to the Green BIM concept implementation in the new construction market - Ghana. These factors has been documented in Chapter 6, research question (Q3). Among all of the barriers that against the success of this Green BIM concept, are the construction culture resistance to new innovation and poor technological edge (levels) in the construction industry in Ghana stands out. Furthermore, in order to overcome the construction culture more educational programs on Green BIM concept must be launch in any avenue available such as Television, Radio, and Seminars. All the relevant key stakeholders in the construction

sector come on board to promote it use and the massive benefits the nation's contrition market stands to gain. Also, the contribution the green BIM concept will to the Ghanaian economy. Secondly, there is the need for software and hardware investment into the construction industry and with this, Ghana government can take the initiatives as it had been done in United Kingdom and Denmark.

Q4. What is the current level of capacity development for industrial players and the future on Green BIM adaption into the new construction market?

Figure 33, indicating the current level of capacity development in the Ghanaian construction Industry by the survey data collected. (See Appendix A)

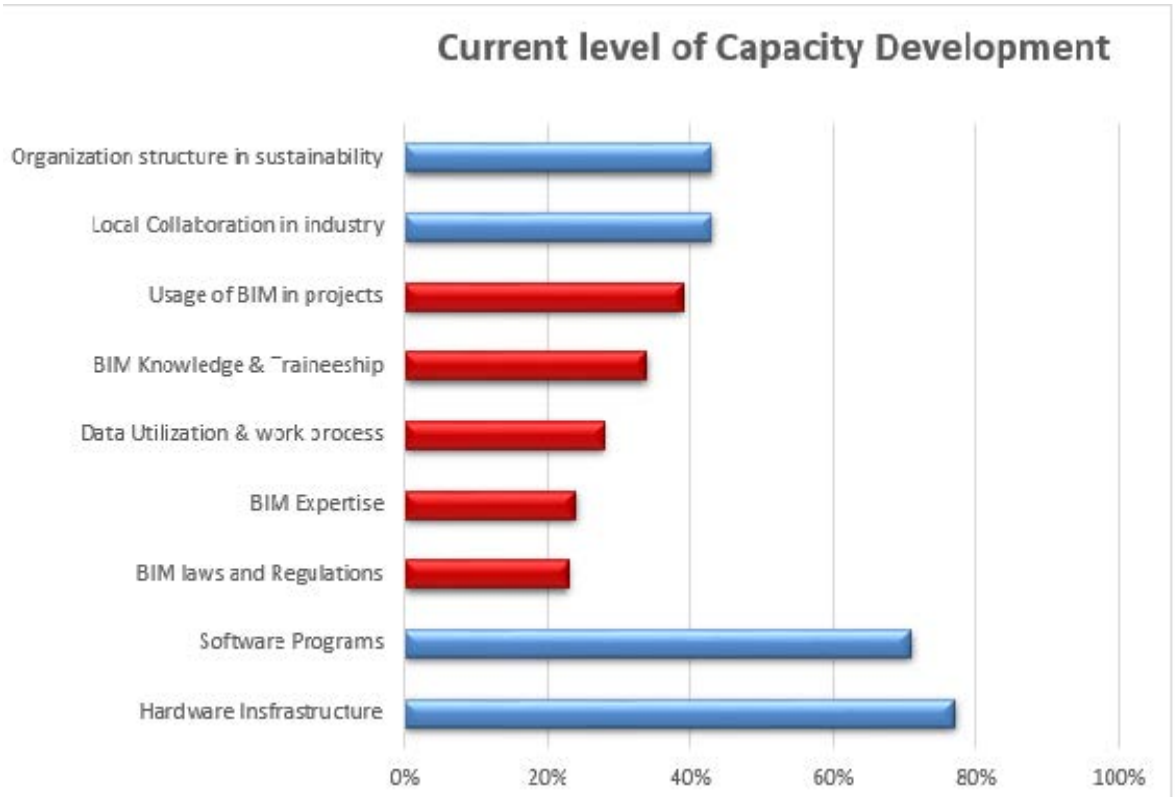


Fig. 33. Current capacity development in the construction industry in Ghana

Therefore, to be able to determine the needed capacity development for the adaptation of Green BIM into the Ghanaian construction industry, the next section of the study investigated the level of capacity development by using 9 items that have been identified in the literature as important capacity measures

for Green BIM implementation. The respondents demonstrated that hardware infrastructure and software programs were available and used in the construction industry.

The results were 77% and 72% for both respectively. This is an essential indicator that Green BIM concept can be implemented. In contrast, BIM law and regulation (23%) and BIM expertise (24%) indicates a low level of capacity development. This is also consistent with other findings in the previous section of this research work, where stakeholders emphasized that one of the challenges were legal challenges and the lack of professional challenges. Stakeholders repeated concern about the human resources and expertise and the legal structure of the Ghanaian AEC/FM industry calls for measures to address these shortcomings so that Ghanaians construction industry can effectively adapt and implement Green BIM concept. The solution for these challenges will be provided in the next section of this research.

Current work processes within the Ghanaian industry in relation to data utilization is another poorly developed capacity. Industry players like the Architects, Contractors, Engineers, Project Managers and Facility Managers who took part in this study were of the view that their data utilization is woefully underdeveloped and that present work processes are not highly efficient meaning that there is the need to develop their capacity in the aforementioned areas. BIM knowledge, usage of BIM, local collaboration and organizational structure are other areas that can benefit from improved capacity strengthening for Green BIM adaptation and application in the construction industry in Ghana.

6.6 Infrastructure of BIM Development Analysis

The infrastructure of BIM development highlights some of the areas which greater attention should be given by the key stakeholders identified in the previous sub-chapter 6.3 in respect to this thesis report main objective. In figure 33, the red bars represent the areas in the capacity development which is at critical state which resources needs to invest in order to promote BIM adoption in construction market and also bring sustainable development to the industry. The light blue is not threats but little bit of attention needed to promote growth and technological advancement for smooth takeoff for the adaptation and implementation of the Green BIM concept in the Ghanaian construction industry for the betterment of civil society and environmental friendly infrastructure development.

Summary:

The current level of capacity development needs to be strengthening and upgrade technologically especially areas that indicates red bars on figure 33 of the current capacity development graph. The findings of the current state of capacity development in the construction sector point to the fact that, there is high potential in the new construction market for the implementation of Green BIM concept. The Government and other professional bodies must invest resources into the operations in the AEC/FM industry in order to harvests the dividends of the initial investment. To this end, the researcher can conclude on it analysis that Green BIM concept adaptation and Implementation can thrive well in the Ghanaian construction market even though there are some areas that needs retooling (technological wise) and intensify education.

6.7. Main Problem statement

This study specifically focused its attention on the issues related to inefficiencies in relation to organizational management and the deficiencies in technological upgrades for effective operational process or methods within the Ghanaian construction industry. In accordance to research data analysis and finding the following list of problems is affecting the organization management and operational process in the Ghanaian construction industry.

1. **Lack of analysis tool for the 3D design building model** - Most of smaller construction firms drawings are in 2D and does have the advance to do energy stimulations or analysis on the 3D design Model.
2. **Finances** - It difficult having access to loans or capital especially if the company is not famous.
3. **Difficulties in collaboration with other companies on project executions** - Most of the company does not work together since one company works after the other, so communication and information sharing is a problem
4. **Lack of good data documentation on project**- There is not proper system in place to store or digitalized the drawing productions.
5. **Management of 2D Drawings** - Voluminous 2D drawings and the like are difficult to manage especially when working on the building site.

Chapter 7: Solutions and Recommendation

This chapter will highlights some of important areas within the construction industry in Ghana that much better attention is required in terms of policy and Regulations, Technology upgrades, New organizational management and process strategies for all the stakeholders within the industry. The adaptation of Green building design concept with BIM into the Ghanaian construction market can only be successful for Architecture, Engineering, Construction and Facility Management players if practical commitment is exhibited and this will pave way to address the problems areas identified as results of this research work.

7.1 Summary of findings on Research Questions:

In account of proposing the best solutions and recommendations which has been identified as the result of the data analyzed in chapter 6, the researcher has adopted the three interlocking fields of BIM namely Process Filed, Technology Field and Policy Field to outline the findings of this research work for the Ghanaian construction industry stakeholders.

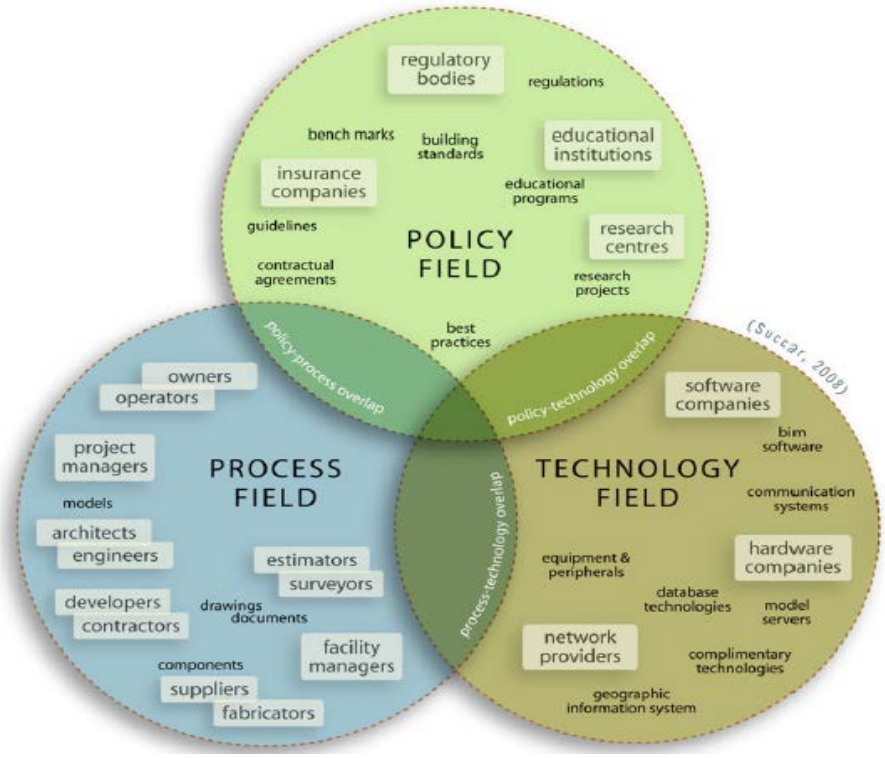


Fig. 34. Three interlocking field of BIM (Succar 2009)

7.1.1Policy Fields

Q1. Are stakeholders open to adopt the Green BIM philosophy and what are their perception of it uses on execution of new projects management in the construction industry in Ghana?

The findings of the stakeholder's interest of Green BIM concept implementation into the Ghanaian Construction industry is very positive and encouraging. The respondents 86% do welcome this innovative technology and have the conviction that this will bring some kind of efficiency and effectiveness into the construction market in Ghana. About 95% appreciate the idea of promoting sustainability in the construction sector will yield higher percentage in environmental consciousness and also transforming the landscape of the nation building infrastructures. The most important concern from the stakeholders, was the Government should take proactive steps to make policies and legislations that enforced the use of Green BIM concept in order of achieving sustainable construction sector with near zero emission. On Construction management, the Green BIM concept will enhance constructability, project scheduling and the like which causes problems for companies in the industry.

Recommendations:

1. Government have to establish an independent BIM Development Task Force who will work under the Ministry of Works and Housing. It responsibility is educating the construction industry on the benefits of Green BIM uses in Constructions management and liaising AEC/FM Industry on BIM implementation and development in Ghana
2. Moving the construction industry towards Sustainable construction requires laws and legislation which requires stakeholders to adhere to, so there must be dialogue between Government and all stakeholders in the construction sector. E.g. all public funding projects must have a contractual agreement on the use of Green BIM concept as requirement for qualification.
3. Government has to review all University and Polytechnic studies curriculum in order to propagates Green BIM concept in large segments of the population as it is in Scandinavian and United Kingdom
4. Research Centers and Professional bodies have to assist Government in policy design, most especially the drafting of standard requirement of Green BIM use in Ghanaian construction industry.

7.1.2. Process Fields

Q2. How will Green BIM improves project management team's collaboration, efficiency in information sharing, project scheduling and project delivery system for AEC/FM industry in Ghana?

All the problems identified which is related to organizational management and operational process is due to poor technological tools and Human relation management except Finances. The days of traditional style of design process or building has come to end especially the construction sector in Denmark and Europe in general. This findings goes to say that, any company or nation who wish to compete in the global construction market must invest in innovative technology like BIM and also develop the human resource capital. Today's technology goes along side with human competencies and in turns yields higher productivity which brings good returned of investment for the company's business or boast growth the nation's Gross Domestic product (GDP). The proposal of Green BIM concept can address all fore mentioned main problems as stated in sub-chapter 6.7. the illustration of Macleamy Curve shows in figure 30 shows the avenue in which BIM technology implementation can offer to the Ghanaian construction industry most especially for the works of Architects, Engineers, Contractors, Facility managers and so forth. This same tools can used to perform all kind of analysis, project scheduling, information sharing and building model stimulations within the built environment.

Recommendations:

1. Government should give incentives like tax reductions to companies who's invest IT software
2. Construction Stakeholders should form partnerships with Financial Institution to grant them loans to uplift their businesses through acquisition on advance technologies
3. Stakeholders in the construction industry to organized seminars and conferences to promote new technologies which is trending in the Ghanaian construction industry or in America or Europe.
4. Educational and Traineeship programs should be made for employees to upgrade their knowledge capabilities.
5. Government and Ghana AEC/FM industry must invest in training more workers on BIM specialist in the next 3 years

7.1.3Technology Fields

Q3. What are the barriers for the success of Green BIM concept adoption and implementation for the AEC/FM industry in Ghana?

The findings of the researcher analysis has indicates there are some barriers which can be an obstacle to the Green BIM concept implementation in the new construction market - Ghana. These factors has been documented in Chapter 6, research question (Q3). Among all of the barriers that against the success of this Green BIM concept, are the construction culture resistance to new innovation and poor technological edge (levels) in the construction industry in Ghana stands out. Furthermore, in order to overcome the construction culture more educational programs on Green BIM concept must be launch in any avenue available such as Television, Radio, and Seminars. All the relevant key stakeholders in the construction sector come on board to promote it use and the massive benefits the nation's contrition market stands to gain. Also, the contribution the green BIM concept will to the Ghanaian economy. Secondly, there is the need for software and hardware investment into the construction industry and with this, Ghana government can take the initiatives as it had been done in United Kingdom and Denmark.

Recommendations:

1. Government and AEC/FM industry must intensify the promotion of Green BIM practices as against construction culture resistance
2. Laws and policies on sustainability practices must be reviewed and enforced in the industry.
3. Investment in professional BIM experts
4. Educational programs on Green BIM in the University and Polytechnics

Q4. What is the current level of capacity development for industrial players and the future on Green BIM adaption into the new construction market?

The current level of capacity development needs to be strengthening and upgrade technologically especially areas that indicates red bars on figure 33 of the current capacity development graph. The findings of the current state of capacity development in the construction sector point to the fact that, there is high potential in the new construction market for the implementation of Green BIM concept. The Government and other professional bodies must invest resources into the operations in the AEC/FM industry in order to harvests the dividends of the initial investment. To this end, the researcher can conclude on it analysis that Green BIM concept adaptation and Implementation can thrive well in the Ghanaian construction market even though there are some areas that needs retooling (technological wise) and intensify education.

Recommendations:

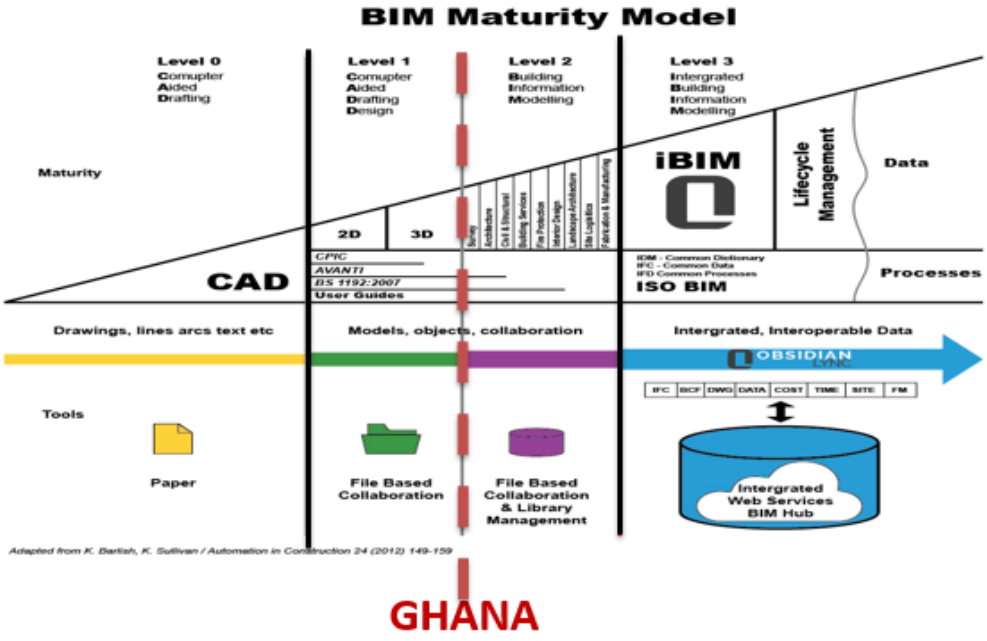
1. Investment in BIM software programs
2. Digitalize the construction industry to monitor rate of development
3. Investment in Hardware acquisitions
4. AEC/FM Industry organizing BIM traineeships to it members
5. Invite foreigner BIM specialist from Europe to develop the human resource capital on BIM

Chapter 8: Implementation

This chapter represent an overview roadmap strategy adopted by the researcher to implement the Green BIM concept to the Ghanaian construction Industry. The BIM Technology strategy used in Scandinavian and United Kingdom will be the researcher guide for the BIM implementation in Ghana. There will be action plans that needs to follow suit for the success of this Green BIM concept.

8.1Green BIM Implementation in Ghana

According to BIM Industry Working Group (BIWG) (2011), the BIM maturity model "wedge" is design to give clear articulation on the stages of competence position in respect to standards, technology and note of guidance. More so, the kind of relationship they have and how they can used contracts and project. It has from 0-3 divisions and how work is perform in each stage and defining the position of technology.



A

Fig. 35. Level of BIM maturity model

Definitions of level (0, 3)

- 0 *"Unmanaged CAD probably 2D, with paper /or electronic paper) as the most likely data exchange mechanism*" (BIM Industry Working Group (BIWG) 2011)

- 1. *"Managed CAD in 2 0r 3D format using BS1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structure and formats commercial data managed by standalone finance and cost management packages with no integration".* (BIM Industry Working Group (BIWG) 2011)
- 2 "*Managed 3D environment held in separate discipline "BIM" tools with attached data commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilize 4D programme data and 5D cost elements as well as feed operational system*." (BIM Industry Working Group (BIWG) 2011)
- 3 "*Fully open process and data integration enabled by "web services" compliant with the emerging IFC/IFD stands, managed by a collaborative model server could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes"* (BIM Industry Working Group (BIWG) 2011)

Based on this report data analysis, the researcher can define the maturity level of the Ghanaian construction industry at level 1 as illustrated on figure 35. The industry deals with file based collaboration with 2D and 3D drawing productions without any energy analysis.

8.2Pilot implementation plan -at Richnash Company Ltd., Ghana

Richnash Company ltd, Ghana is a construction and Engineering Company, located in Kumasi - Ghana. The company which is basically was established in 2007. The firm undertakes different private and governmental projects, it also provides services in the following areas, project planning, tender documentations, facility management, general construction works. Etc.

The company in recent time has not be able to optimize their productivity. Since the researcher had the opportunity to interviewed the project manager. The researcher has recommend to deploy this Green BIM concept to their established for their construction management. During the interview Richard (the project manager) said that the company have the needed infrastructure to try new business strategy. The company will take 12 months to implement the BIM technology concept within the company. The figure 36 illustrate, the target areas in which the company will use this BIM implementation.

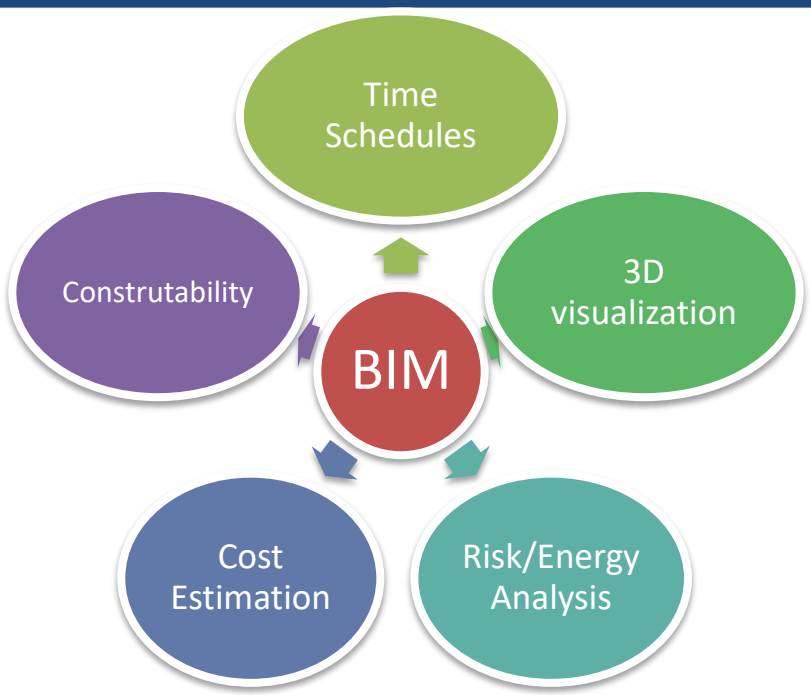


Fig. 36 Focus areas for BIM at Richnash Company Ltd.

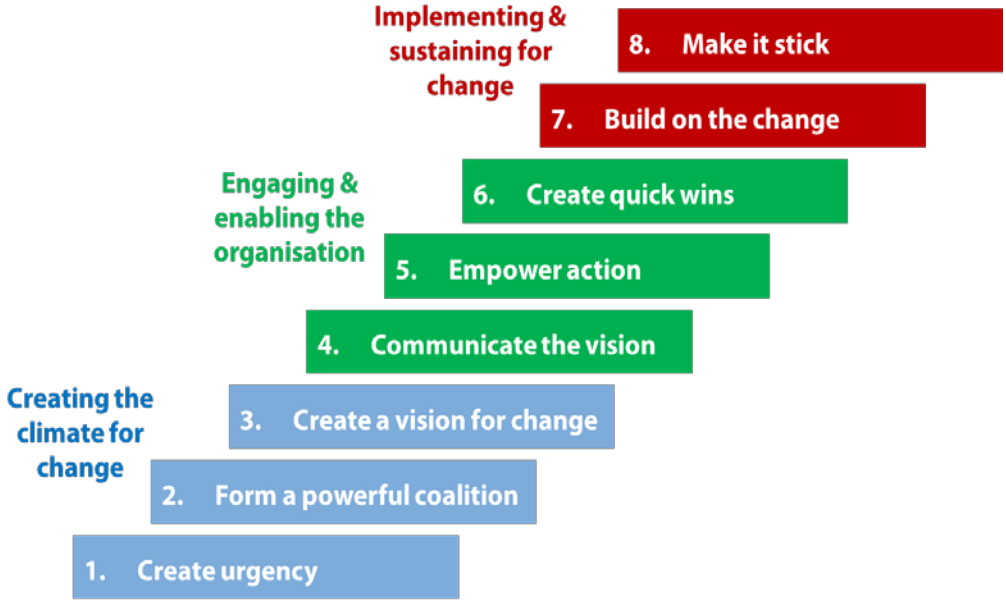


Fig.37 Kotter's Change Model (www.scrumalliance.org)

Action Plan

Phase		Explanation	Responsibility	Allocated Time
Creating Climate for Change	**Step 1**	**Create Urgency:** Firstly, introduce the BIM technology concept to all workers and all stakeholders associate to the organization. Define the areas where the Green BIM concept will be used in the company's business. Repeat the reasons for it implement more than ones for better understanding and working environment.	Project Manager RICHARD	2 week
	Step 2	**Form a Powerful Coalition:** After the introduction of the BIM concept. Select start-up team who will starts the BIM implementation. Recommend that this team should be Top managements and Hire BIM Specialist.	BIM Specialist Project Managers	2 weeks

	Step 3	**Create a Vision for Change:** After the establishment of the team in the firm. The project manager will take charge of the BIM application accordingly by the BIM specialist directions. All the process must be documented and integration of the new system must be systematically	Project Manager	2 weeks
Engaging and Enabling the Organization	**Step 4**	**Communicate the Vision:** The dialogue phase - this where managers and workers engage on the pros and cons on the BIM application. The feedbacks will help to develop and improve the BIM concept. The BIM specialist overseas such event.	BIM Team consisting of the BIM Coordinator and Project Managers	1 month

	Step 5	**Empower Action & Remove Obstacles:** This is stage where individual who are performing well are empower to take more responsibility. Likewise, non-performing employees are set aside.	Project Manager	1 month
	Step 6	**Create quick wins:** Don't be in hurry to use the BIM concept for big projects. starts by little by little steps Workers who participants rewards them with little things to motivate them	Project Manager Richard	6 weeks

Implementing and Sustaining for Change	**Step 7**	**Build on Change:** This stage is where the BIM implementation is finalized. All BIM team will continue to develop their new expertise and also focus on the big picture by projecting the image of the company and its operations	BIM Team consisting of the BIM Specialist and Project Managers	6 months
	Step Number 8	**Anchor Changes Made:** This is the evaluation stage. Making sure that the performance given so far are good and has the BIM implementation has brought change as compare to when the all process started. Records must taking to monitor	BIM Team consisting of the BIM Specialist and Project Managers	1 month

		the development level of the BIM concept		
			Project manager RICHARD	

Table 1. Implementation Action Plan.

Chapter 9: Conclusion

This chapter represent the conclusion of the entire Master's Thesis Project report on the Adaptation of Green building design concept with BIM into the new construction market - Ghana. The summarizes of this report findings will enable the construction industry stakeholders to make significant decisions and take a proactive measures to addressed the problems of inefficiency in construction management and technological deficiency as documented in this research work. A proposed future research development is outline for other researchers to take on for the betterment of Ghanaian construction industry and beyond.

In this thesis report, the researcher started it with one simple question in mind "How can we do it Ghana?" The quest to seek knowledge and to contribute to the development of the country of my birth was the driving force. The primary objective of this research work was centered on how best the Ghanaian construction industry can take advantage of the use of Green building design concept with BIM in their construction management and project delivery system as compare to what people experience in Scandinavian and United Kingdom.

The outcomes of the researcher's findings discover an antidote of implementing the Green BIM concept in the Sub-Saharan country of Ghana if the rightful structure are put in place for the take-off of this concept. Having said that, there is also huge potential construction market in Ghana and Africa in general, who are interested to explore this innovative technology called Green BIM. The following are the findings and the responsibility that comes with it.

1. Government have to establish an independent BIM Development Task Force who will work under the Ministry of Works and Housing. It responsibility is educating the construction industry on the benefits of Green BIM uses in Constructions management and liaising AEC/FM Industry on BIM implementation and development in Ghana
2. Government has to review all University and Polytechnic studies curriculum in order to propagates Green BIM concept in large segments of the population as it is in Scandinavian and United Kingdom
3. Construction Stakeholders should form partnerships with Financial Institution to grant them loans to uplift their businesses through acquisition on advance technologies

4. Government have to take initiative by investing into Hardware acquisition and software programs for the industry
5. Inviting foreigner with BIM specialist from Europe to develop the human resource capital on BIM
6. Government should give incentives like tax reductions to companies who's invest IT software
7. Laws and policies on sustainability practices must be reviewed and enforced in the industry
8. Moving the construction industry towards Sustainable construction requires laws and legislation which requires stakeholders to adhere to, so there must be dialogue between Government and all stakeholders in the construction sector. E.g. all public funding projects must have a contractual agreement on the use of Green BIM concept as requirement for qualification.
9. Government and Ghana AEC/FM industry must invest in training more workers on BIM specialist in the next 3 years
10. Research Centers and Professional bodies have to assist Government in policy design, most especially the drafting of standard requirement of Green BIM use in Ghanaian construction industry.

The researcher have the convictions that if all these points are execute to it perfection it will answers all the research questions in chapter 1. Again, the Kotter's 8 steps action plan in chapter 8, will come handy when implementing this concept into the new construction market -Ghana for AEC/FM industry.

Future Research Recommendations

"It is recommended that future research could be carried out on the use of BIM in Rural Housing Development for aging people"

Finally, there is a saying *"Do not be the same, be better"*. The researcher dream of seeing a vibrant Ghanaian construction industry operating with modern technologies that makes their work effective and efficient.

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