Building Information Modelling Adoption in Structural Design in Kenya - A Case Study of Nairobi.

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Abstract
Countries like the USA, UK and the Netherlands have all adopted Building Information Modelling as a standard and it is used in the design and construction process. In Kenya, neither is the use of Building Information Modelling mandatory nor has it been made a standard for any form of work. Its adoption is purely based on the organizations policies and preferences.

This paper seeks to explore the adoption of Building information modelling in Structural design. The research design employed was a survey research. Primary data was collected through a well-structured questionnaire using a sample size of forty respondents. Based on the findings, Building Information Modelling is in use in majority of the organizations. However, for the majority Building Information Modelling had been in use for under 3 years indicating that adoption of Building Information Modelling in Kenya is quite recent.

The major hinderances to Building Information Modelling adoption were found to be, the cost of the software, lack of trained personnel and lack of knowledge and awareness. To encourage Building Information Modelling adoption, it is recommended that, it is included in the Engineering curriculum, the use of Building Information Modelling is promoted among Construction Industry professionals by creating and increasing awareness through workshops and conferences and making the software cheaper and accessible.

Key words: Building Information Modelling, Structural Design

1. Introduction

Globally in construction, digitalization has progressively taken over most processes and structural design is one of them. There has been a move away from manual design to Computer Aided Design (CAD) to Building Information Modelling (BIM).

The construction industry in Kenya is growing. A statistical release by Kenya National Bureau of Statistics (2018) shows that the growth rate of real estate was 6.8%, 6.6% and 5.8% in the first three quarters of 2018. The government plans, policies and strategies such as the “Big Four Agenda” and “Vision 2030” have contributed to this growth.

In Kenya the Industry players directly affected by Building Information Modelling are Engineers, Architects and Contractors. A study done on Building Information Modelling adoption in Project management, focused mainly on Contractors, Builders and other industry Professionals found that only 25% had adopted it in their firms. (Mumbua, 2016) The same study found that the respondents agreed that the design and construction stages are where Building Information Modelling had the most benefits.

Another study done on the adaptation of Information Communication Technology (ICT) by contractors found that 35% reported using it always, 22% reported using it most times, 41% reported using it quite often and 4% reported using it rarely. (Nyaga, 2016) The significance of this study is that Building Information Modelling adoption is dependent on the use of Information Communication Technology.

Gitee (2018) studied the effects on implementing Building Information Modelling in Projects in Nairobi. The study discovered that when Building Information Modelling is implemented in project design and project estimation it had a positive and significant effect on the project implementation success. However, Building Information Modelling was not being fully relied on for material estimation and project scheduling.

The structural design processes of interest are design conceptualization, interpretation of design, structural analysis, clash detection, trade co-ordination, estimation of quantities, scheduling of work, design documentation, archiving of information and submission to the relevant authorities.

A study on Future Cities and Building Information Modelling found that there was a correlation between the world economic Forums, "Network Readiness Index" and the use of Building Information Modelling in countries. The index is a measure of a countries readiness to exploit opportunities of Information and Communication Technology. (Sielker and Allmendinger, 2018) The world economic forum report of 2016 ranked countries like the USA, UK and the Netherlands as 5th, 6th and 8th respectively whereas Kenya was ranked 86th. It is then no wonder that the USA, UK and the Netherlands also lead in Building Information Modelling adoption.

Table 1 Summary of BIM in the USA, UK and Netherlands

Countries	**USA**	**UK**	**The Netherlands**
Regulatory framework	BIM obligatory for government projects from 2008,	BIM mandate for public procurements, obligatory for government projects by 2016, development of standards	No governmental mandate, state agency today in tenders require BIM standard development
Financial framework	Indirectly through governmental projects,	BIM projects reflected in budget and financial support of institution	Indirectly, through governmental projects
Other elements	Support from federal governments, private stakeholders and universities supporting education	Development of institution and support of BIM community development, construction industry is involved in BIM definition through UK Task group	Marketing campaign, BIM weeks organised by private companies, standard development based on technological experiences
Focus	Initial focus on public service buildings	Focus on infrastructure and private buildings	Initial focus on private buildings, designed by architects etc., public projects focus on infrastructure
Timeframe	Start in 2003, BIM mandate 2007	Start in 2011, BIM mandate 2016	Start of debates in the 90s, early projects leading to standards by 2003, 2012 open BIM standards
Leading Stakeholders	Public entities and organisations	Government with the support of a Task Group including leading BIM companies	Led by construction industry stakeholders

Source: Sielker & Allmendinger, 2018

The National Construction Authority in Kenya is in the draft stages of developing a Construction Industry Development Policy. Listed in the draft among the challenges is the low technological uptake and exposure levels of stakeholders to international best practices. However, the absence of technological uptake as an independent policy objective does not give a platform to address Building Information Modelling. In comparison to the UK, where Building Information Modelling was among the main strategies for their construction Industry Strategies of 2011 and 2016, Kenya falls short.

Methodology

A quantitative approach using a well-structured questionnaire was adopted. The target audience were Structural Engineers registered with the IEK (Institute of Engineers of Kenya) in Nairobi County. Nairobi was selected as it is the Administrative and Economic capital of Kenya.

Random sampling was employed to ensure that the entire population had an equal probability of being selected. The sample size was 40 participants.

Primary data for this research was obtained through administering well-structured questionnaires, mainly comprised of closed and open-ended questions. The questionnaire had 4 parts and a total of 28 questions. The questionnaires were administered through an online link or a printed version delivered to various structural design firms. One questionnaire was delivered to each design firm to allow for a diverse response pool. The response rate was 87.5%. Google sheets was used to analyse the data.

Secondary data was then used to corroborate and draw comparisons from the findings obtained from the primary data. The sources of secondary data included, but are not limited to, books, thesis, journal articles, reports and internet searches.

Results and Discussion

This section presents the data and corresponding analysis obtained from the questionnaires.

3.1. Profession

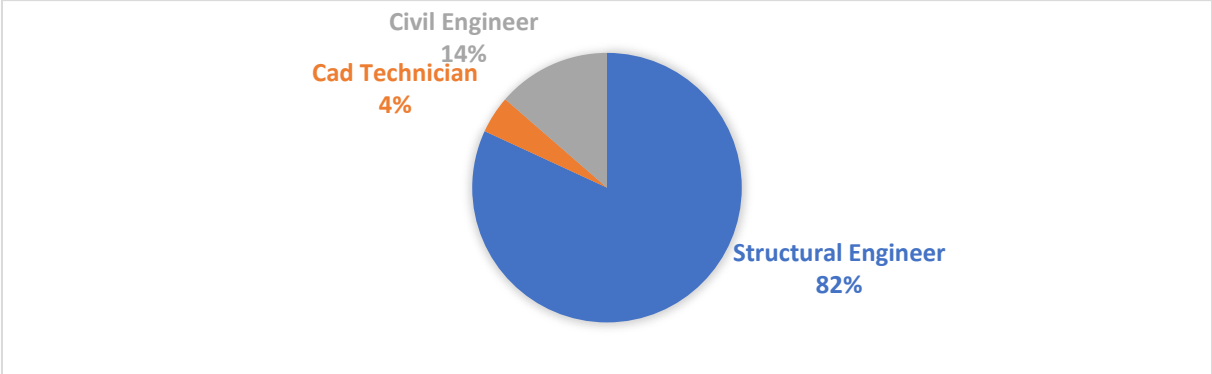


Figure 1 Distribution of Professionals

The percentages of the population surveyed are Structural Engineers at **82%,** Civil Engineers at **14%** and Cad Technicians at **4%**. This distribution is true of their respective involvements in the design processes. Generally, in a structural design, Engineers are involved in all the design processes and Cad Technicians are usually limited to the production of construction drawings and other construction documentation.

3.2. Experience

In order to gauge their proficiency in Structural Design the respondents were asked to indicate their work experience. **53%** of the respondents had 0-5 years' experience, **33%** had 5-10 years' experience and **14%** of the respondents had over 15 years' experience.

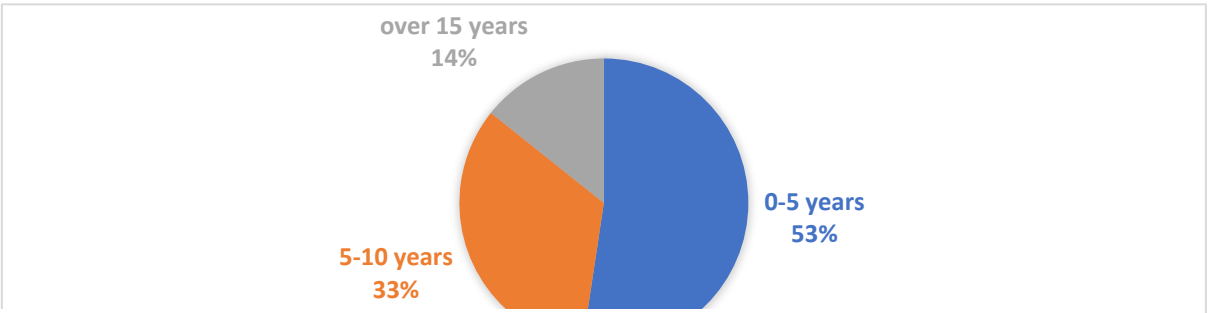


Figure 2 Work experience

3.3. Organization Size

The following criteria was used to classify the organizations:

Number of employees: where a small organization is one that has less than 10 employees, a mid-sized organization is one that has 10-50 employees and a large organization is one that has over 50 employees.

The type of projects handled: Generally, small organizations handle mainly simple residential and commercial projects. Mid-size organizations tend to handle residential, commercial and industrial projects that are complex. For large organizations, most of the projects they work on have government involvement, international funding and are major industrial projects that require heavy capital.

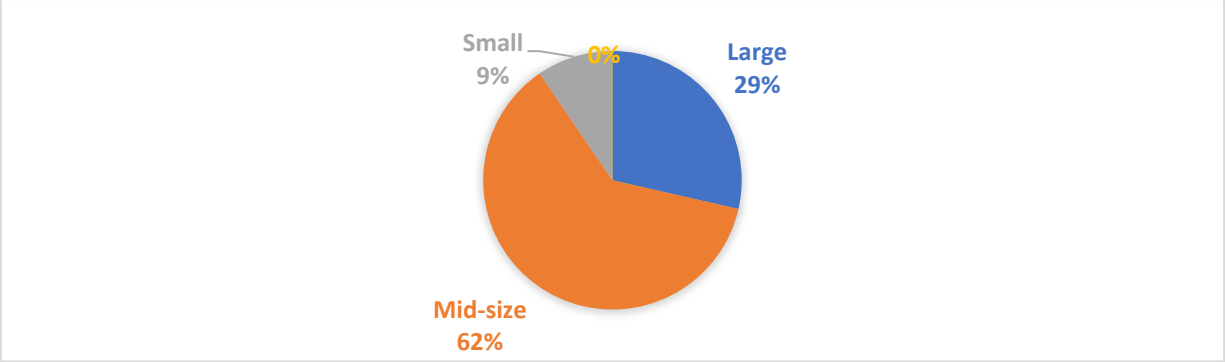


Figure 3 Organization Size Distribution

Of the organizations surveyed **61.9%** were mid-size organizations, **28.6%** were large organizations and **9.5%** were small organizations.

It is indicative of the distribution of organization sizes within the Engineering sector in Kenya. This is attributed to the complexity of the available projects. The country is still developing, and a large percentage of the clients are homeowners, residential developers and commercial developers. Such projects would be an underutilization of resources for large firms. As for small firms they may not be able to keep up with the constant need for data or may only be able to handle one project at a time. Thus, the Mid-sized organizations thrive as it is an optimal and sustainable use of resources.

3.4. The individual level of awareness of BIM.

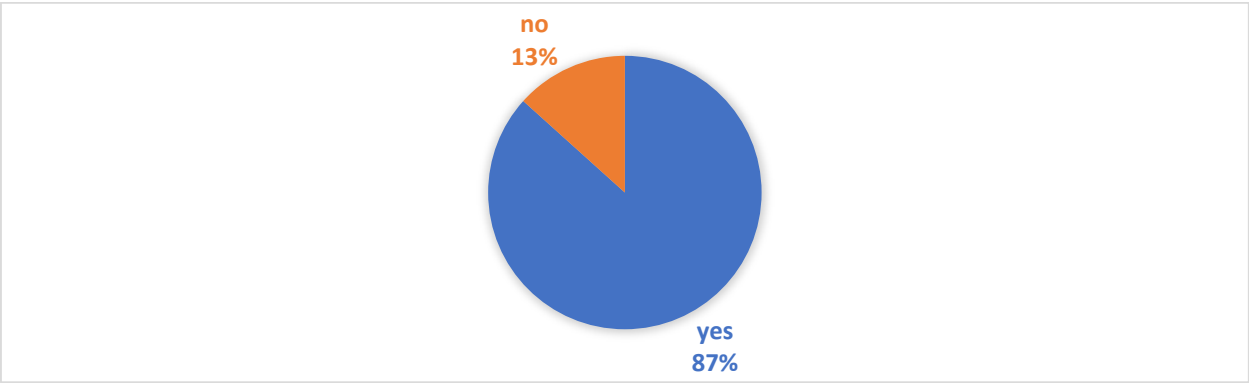


Figure 4 Level of BIM awareness

In order to gauge the general level of awareness on Building Information Modelling and level of understanding concerning its application in structural design the respondents were asked whether they knew about Building Information Modelling.

Majority of the respondents (**87%)** answered in the affirmative, that they were aware of Building Information Modelling and (**13%)** reported a lack of awareness of Building Information Modelling.

Mumbua (2016) obtained similar results in a study on Building Information Modelling adoption in construction project management. It can then be inferred that there is a high level of awareness of Building Information Modelling in the construction industry in Kenya.

3.5. The use of BIM in design in the organization.

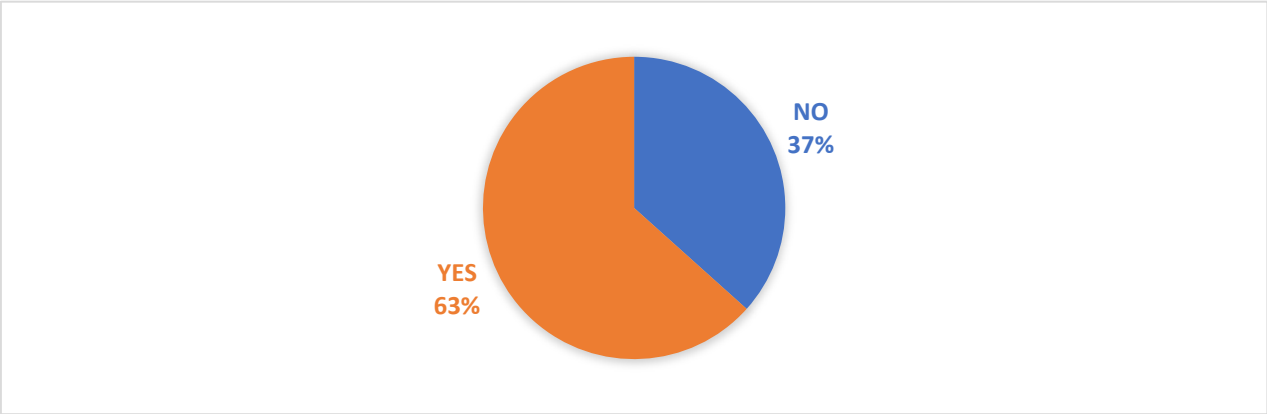


Figure 5 Organizational BIM use

The use of Building information modelling within the organisations was then established. **63%** reported the use of Building Information Modelling within their organisations while **37%** reported that Building Information Modelling was not being used in the organisation.

As compared to findings by Mumbua (2016) where only **25%** were using Building Information Modelling, there is a wider use of Building Information Modelling in structural design.

Building Information Modelling is an integrated workflow that involves all industry professionals. When the above data sets are compared, they indicate that Engineers use Building Information Modelling more than Construction Project Managers. Indicative of an inefficient use of Building Information Modelling as a coordination tool across the industry.

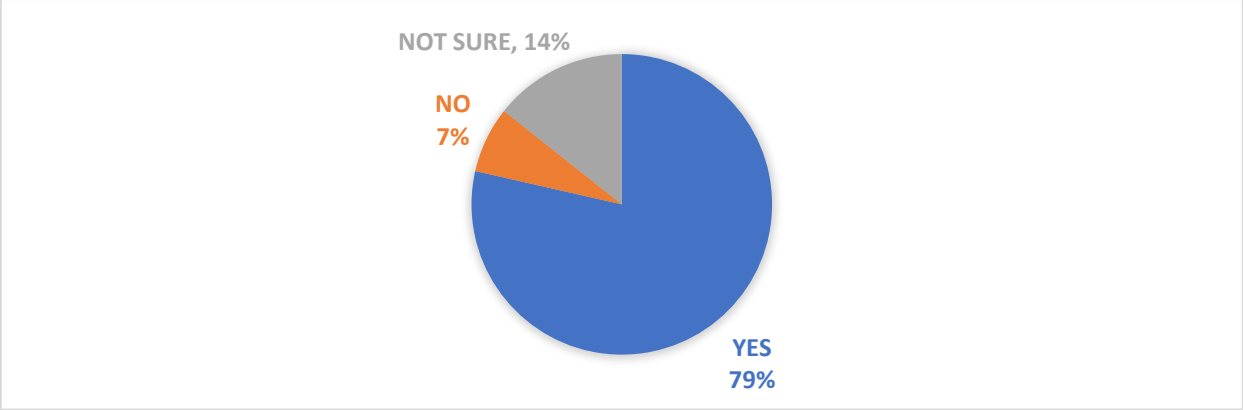


Figure 6 Possibility of Future BIM adoption

From **Figure 5**, of the **37%** that reported a lack of use of Building Information Modelling, **78.6%** thought it would be adopted soon, **7.1%** thought it would not and **14.3%** were not sure.

Similar statistics by Mumbua (2016) found that a majority thought it would be adopted soon. Showing that most professionals do realise that Building Information Modelling is essential and beneficial to the construction Industry.

3.6. Number of years BIM had been in use

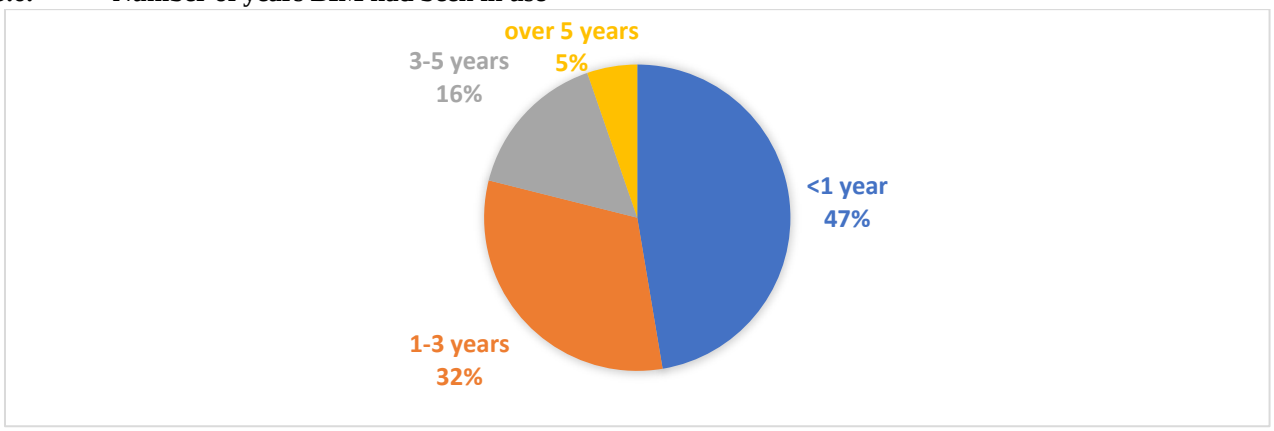
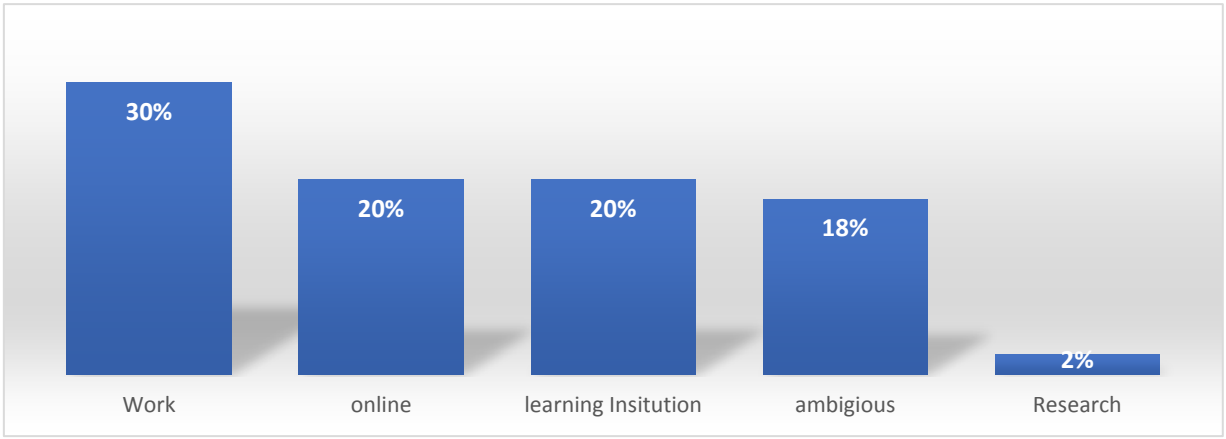


Figure 7 *Length of use of BIM.*

Of the **67%** who said that Building Information Modelling was in use in their organizations, **5%** said that it had been in use for over 5 years, **32%** said 1-3 years and **16%** said 3-5 years and **47.4%** said it had been in use for less than a year. This shows that there is an increase in the number of organizations adopting Building Information Modelling.



3.7. First BIM encounter

Figure 8 First BIM encounter

The respondent's first Building Information Modelling encounter was then established. Majority (**30%**) reported to have encountered it at work. This was closely followed by learning institutions, and Online activity at **20%. 7%** of respondents reported that they had encountered it in research. There were some unclear responses which came to (**18%**).

This is indicative of a clear variation in the syllabus of institutions of higher learning especially universities and that many graduates only encounter Building Information Modelling after they leave the learning institutions.

3.8. Rated level of adoption in the organizations

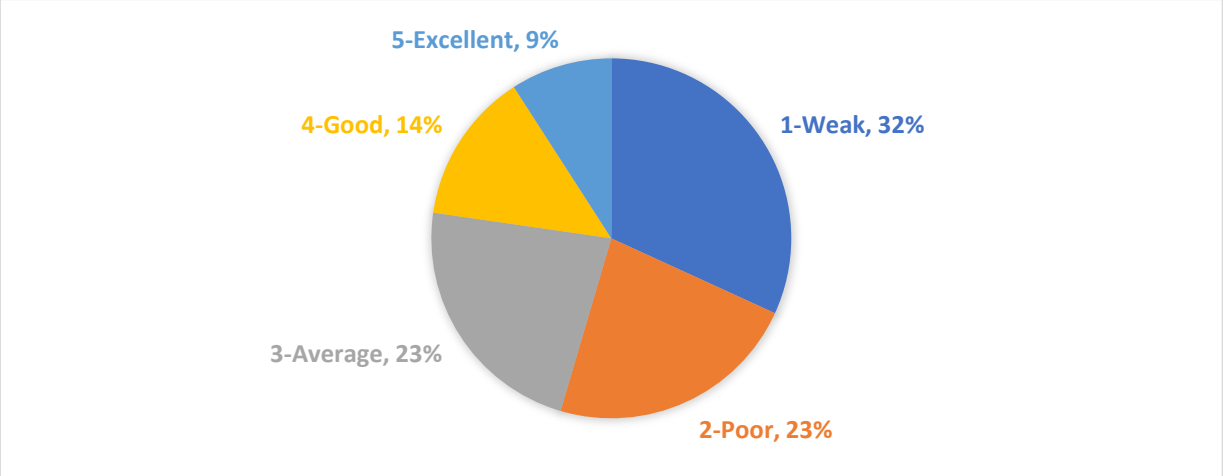


Figure 9 Level of BIM adoption

On the overall level of adoption of Building Information Modelling the results were as follows. **32%** of respondents rated the level as weak, **23%** of respondents rated the level as poor, **23%** of respondents rated the level as average, **14%** of respondents rated the level as good and **9%** rated the level as excellent.

As majority of respondents gauged the level of adoption as poor and weak, this shows that although most organizations are using Building Information Modelling it has not been fully integrated into the design process.

3.9. Use of the latest versions of the software.

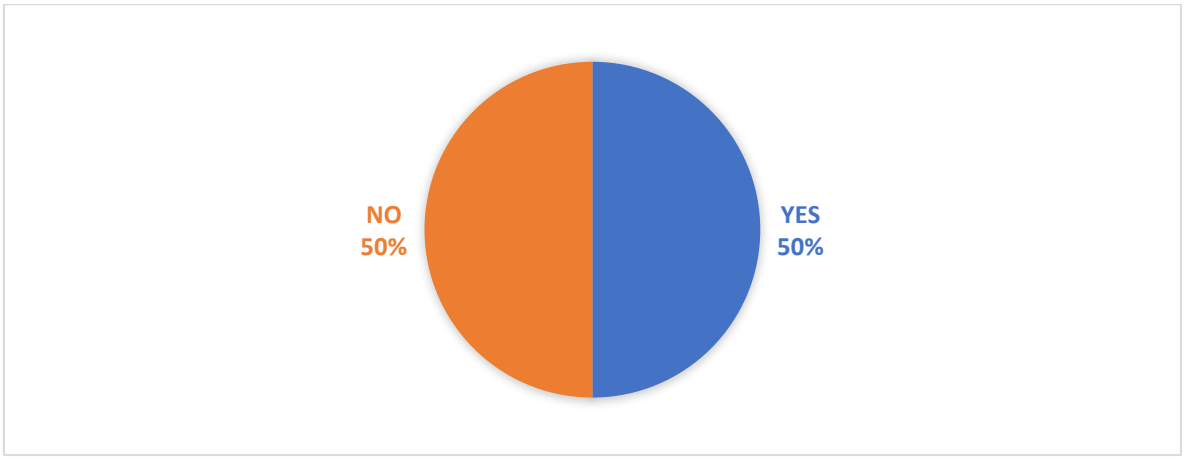


Figure 10 Use of the latest versions of software

Building Information Modelling software like most software are updated yearly. For example, Autodesk products are updated a minimum of yearly. With regards to whether organizations kept up with updated versions of the software the distribution was a **50-50** split. The use of up to date software is attributed to the recent adoption of Building Information Modelling by most organizations, as seen in **Figure 7** as they are likely to use the up to date software.

3.10. Design Processes in which BIM is used

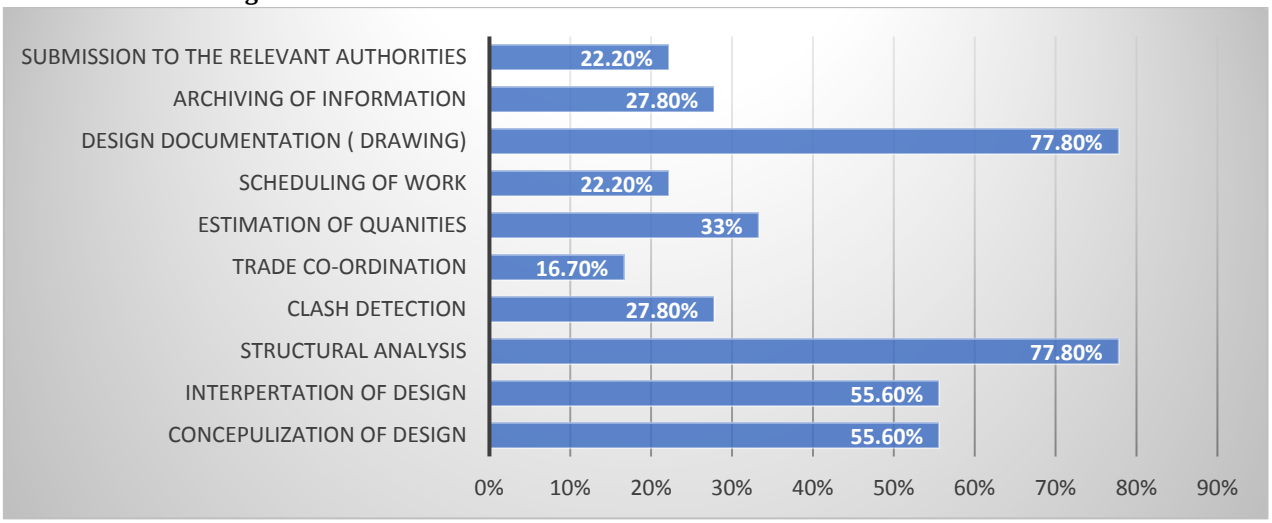


Figure 11 BIM use distribution in design Processes

The main uses of Building Information Modelling are Structural Analysis and Design Documentation (Drawings) **77.8%.** In the past Computer Aided Design was heavily and almost absolutely used in these two processes. It is no wonder then, that there has been a large progression to Building Information Modelling.

Respondents reported using Building Information Modelling in Interpretation of design and conceptualization at **55.6%.**

33.3% reported using Building Information Modelling in the estimation of quantities. A study on the effects of implementing Building Information Modelling in Nairobi found that majority of respondents agreed on the benefits of adopting Building Information Modelling in project estimation. (Gitee 2018) However, it was found that Building Information Modelling was rarely used in project estimation. This shows a prevailing use of other methods of quantity estimation or delegation of quantity estimation to Quantity Surveyors or Construction Project Managers.

27.8% of respondents reported using Building Information Modelling for Clash Detection and Archiving of Information and Documentation. In comparison to a study on the effects of implementing Building Information Modelling in Nairobi where majority of respondents agreed that Building Information Modelling boosted clash detection, (Gitee, 2018) the use of Building Information Modelling in clash detection is wanting.

Only **22.2%** of respondents were using Building Information Modelling to submit documents to the relevant authorities. On November 28, 2018, the Nairobi County changed the way documents were submitted for approval. With the opening of a new "eDevelopment Permit Management System" (e-DPMS). The system enables the submission of building plans online, submitted by Construction Industry professionals, to various departments of planning within the Nairobi City County for vetting and approval. Despite the submission being online, the standard has not been set as Building Information Modelling, which then contributes to the low percentage.

22.2% of respondents reported using Building Information Modelling in scheduling of work. This is indicative of the presence of other software such as MS Project which has been the traditional design tool for scheduling work. This corelates to a study on the effects of implementing Building Information Modelling in Nairobi, where it was found that majority of respondents were uncertain of the effect of Building Information Modelling in project scheduling. (Gitee, 2018)

The design process where Building Information Modelling is used the least is trade coordination where only **16.7**% of respondents reported its use. This is attributed to the disparity in coordination tools between construction industry professionals, Quantity surveyors and Construction Project Managers in the industry.

3.11. The level of application in the specific design processes

The respondents were asked to evaluate the use of Building Information Modelling in various design processes on a 5-point scale where 5 = excellent, 4 = good, 3 = average, 2 = weak and 1 = poor.

Table 2 Level of BIM application in design processes.

Area of use of BIM	*Mean*	*Variance*	*Standard Deviation*
Conceptualization	2.28	1.60	1.26
Interpretation of design	2.52	1.89	1.37
Structural Analysis	2.52	1.96	1.40
Clash detection	2.09	1.61	1.27
Trade co-ordination	1.87	1.41	1.19
Estimation of quantities	2.33	2.27	1.51
Scheduling of work	1.98	1.99	1.41
Design Documentation (Drawings)	2.75	2.29	1.51
Archiving of Information	1.83	1.96	1.40
Submission to relevant authorities	2.28	1.60	1.26

All the means were below 3, indicating a weak to average level of application even for the design processes that Building Information Modelling was heavily relied on. The data has a standard deviation ranging between 1.508-1.198 which indicates that most of the data lies around the mean.

It also shows that despite the use of Building Information Modelling in organizations, it is not fully relied on and may be supplemented by more traditional design alternatives such as CAD and manual methods. In comparison to the UK, Kenya would be ranked as Level 1 Building Information Modelling whereas the UK is moving towards Level 3 Building Information Modelling. This puts the Construction industry in Kenya in comparison to the UK between 10-20 years behind.

3.12. Factors hindering the adoption of BIM

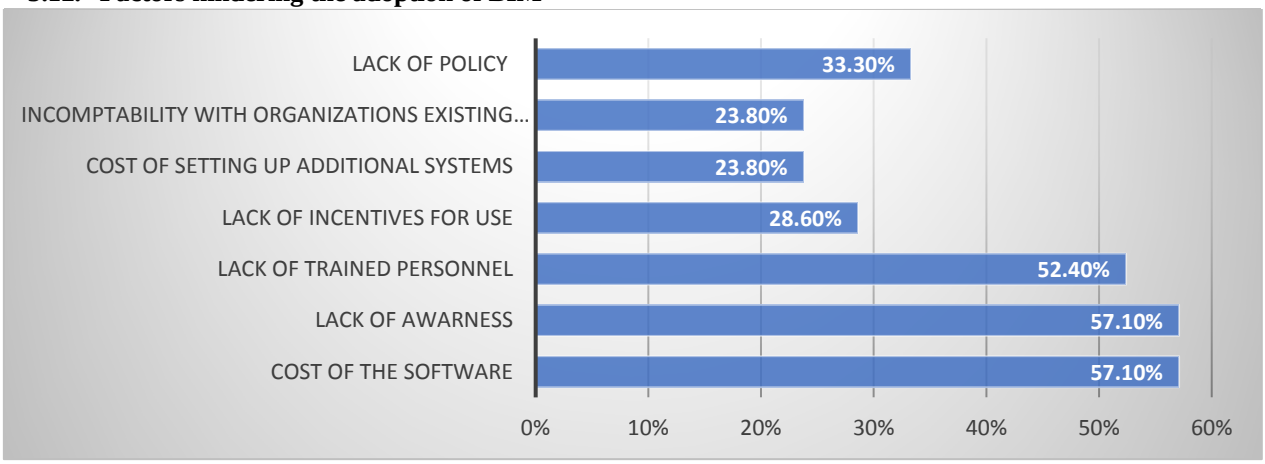


Figure 12 Hinderances to BIM adoption

57.1% of respondents agreed that the cost of the software hinders the adoption of Building Information Modelling. For instance, to buy the Autodesk Revit Structure software plus license from Autodesk costs 2,250$ (225,000 KES) per year exclusive of tax and other expenses. (Autodesk.com, 2019) A re-seller of Autodesk costed the same software at 168,000KES +VAT per year. This covers the cost of one license per device. Depending on the size of the organization, the number of required licenses would also vary leading to a proportional increase in cost.

57.1% of respondents reported that lack of awareness Building Information Modelling greatly affects its adoption. It is almost impossible for people to adopt something they are unaware of. The lack of awareness is perpetuated by the training given to construction industry professionals. The institutions of higher learning tend to focus on 'First Principles' of the design and may not be too keen on the technological aspects of the design process.

52.4% of respondents reported that lack of trained personnel is a hinderance. Building Information Modelling is relatively new to Kenya and many engineers are already used to using other methods and may not have the required training to use Building Information Modelling.

33.3% of respondents reported that lack of policy is a hinderance. Unlike the UK, Kenya has no governmental strategy that pushes or promotes the adoption of Building Information Modelling. Neither is it mandatory for the use of government projects as compared to the USA. Thus, the construction industry professionals are free to make the decisions on what design tools to use and are not compelled to use Building Information Modelling.

28.6% of respondents reported that lack of incentives for use and incompatibility with organizations existing structures as hinderances. Regarding the cost of setting up additional systems **23.8%** of respondents reported it as a hinderance**.**

This indicates that lack of incentives for use, incompatibility with organizations existing structures and the cost of setting up additional systems may not be major aspects hindering the adoption of Building Information Modelling and may only be applicable at an organizational level.

3.13. The Necessity for BIM adoption

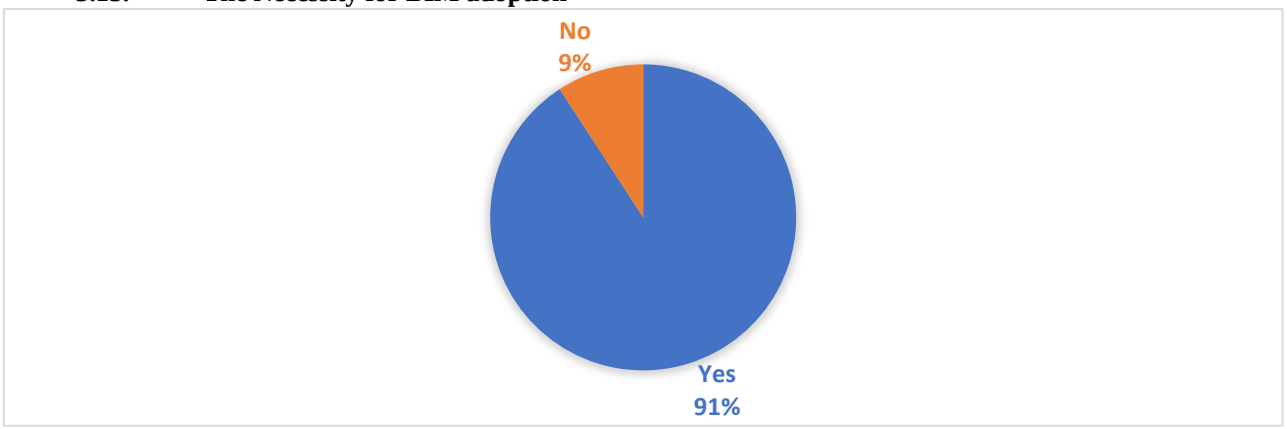


Figure 13 Necessity for BIM adoption

In order to gauge the future of Building Information Modelling in the country the respondents reported their opinion on the necessity of Building Information Modelling adoption. **91%** of respondents agreed that Building Information Modelling is necessary in Kenya.

9% of respondents reported they did not think it was a necessity.

3.14. Awareness of the use of BIM internationally

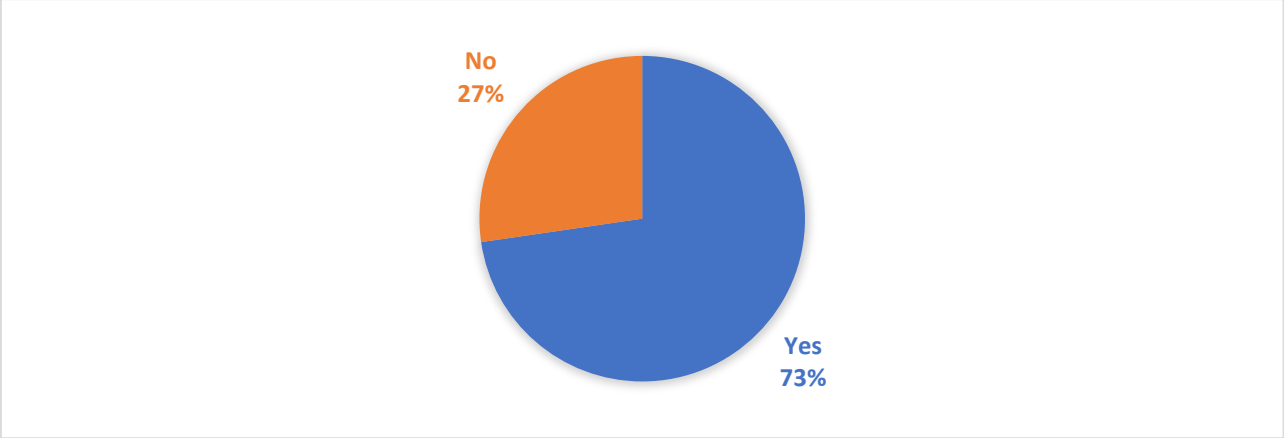


Figure 14 Awareness of International BIM use

In the recent past the construction industry in Kenya has had an increasing number of international companies involved in the various construction processes. The aim was to determine how Kenyan firms, compete in this environment and the impact of the design processes and tools used by the international firms.

73% of respondents were aware of Building Information Modelling adoption in other countries, were as **27%** of respondents were not aware.

3.15. Responsibility to push for the adoption of BIM

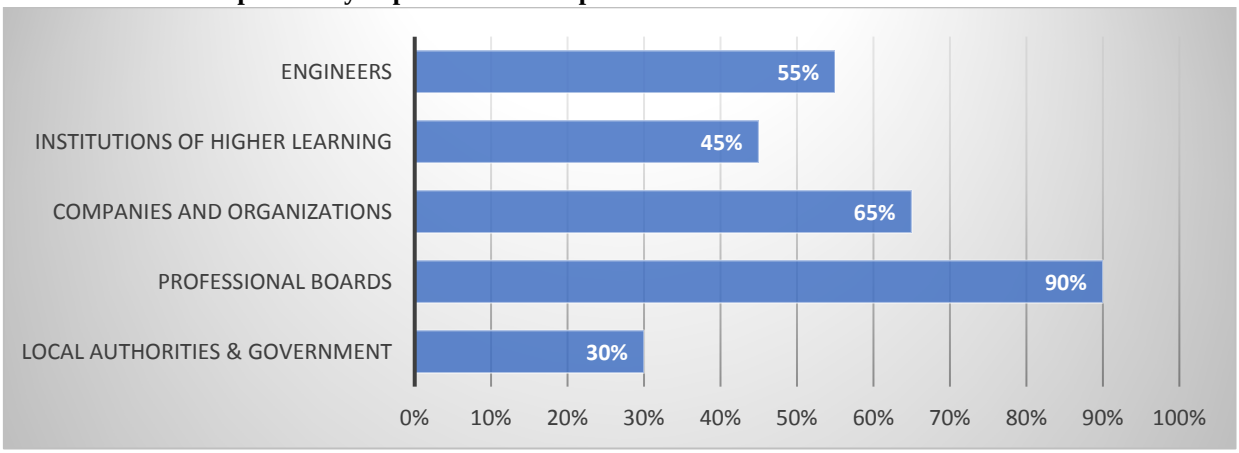


Figure 15 Responsibility to push for BIM adoption.

90% of respondents agreed that it was the responsibility of Professional Bodies to push for Building Information Modelling adoption. This is because they accredit and regulate the industry and thus are better placed to impact organizations and engineers.

65% of respondents reported that the responsibility to push for Building Information Modelling adoption was with the Organizations. Since change is easier when it is internal, here the pace of adoption would be controlled by the organization and customized to suit the organization's needs.

55% of respondents reported that it was the responsibility to push for Building Information Modelling adoption was with the engineers. This is mainly because they are the ones who directly benefit from it and have the capacity to influence the professional bodies, government and organizations to make the necessary change that would see adoption of Building Information Modelling.

45% of respondents reported that it was the responsibility to push for Building Information Modelling adoption was with the institutions of higher learning. Whereas **30%** of respondents reported that the responsibility lies with the government.

As professional bodies have the highest percentage, the most likely path that the Kenyan construction industry will follow with regards to Building Information Modelling adoption is that of the Netherlands. Where Building Information Modelling adoption was led by construction industry stakeholders. Below is a comparison between Kenya and the Netherlands, the similarities have been highlighted.

Table 3 Comparison between Kenya and the Netherlands

Countries	**Netherlands**	**Kenya**
Regulatory Framework	No governmental mandate, However, state agency currently requires BIM standard development	No governmental mandate. No requirement of BIM standard development
Financial Framework	Indirectly, through governmental projects	Organizational
Focus	Initially on private buildings.	Initially on private buildings.
Timeframe	Start in 90's, standards by 2003, open standards by 2012	Start in the 2010's gradual growth from then.
Leading stakeholders	Construction Industry	Construction Industry
Other Elements	Marketing Campaigns, BIM weeks organized by private companies, Standards based on Technological experiences	BIM talks organized by companies and institutions of higher learning. Standards are based on the companies.

3.16. Would a change in Policy affect BIM adoption?

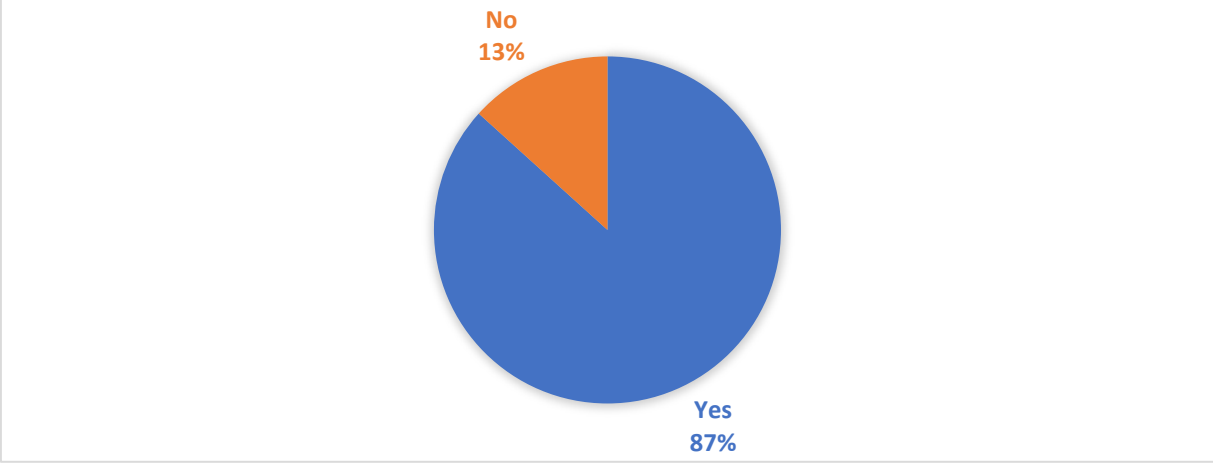


Figure 16 Effect of Policy change on BIM adoption

Majority of the respondents **87%** believed a change in Policy would increase the adoption of Building Information Modelling. Where, policy is a set of regulations, which form the base of day to day decisions. This is supported by the UK government Strategy (2011) where Building Information Modelling was mandated for public procurement, this has contributed to an increase in the level of Building Information Modelling adoption in the UK.

13% of respondents did not believe a change in policy would affect Building Information Modelling adoption.

3.17. Formulation of Policy

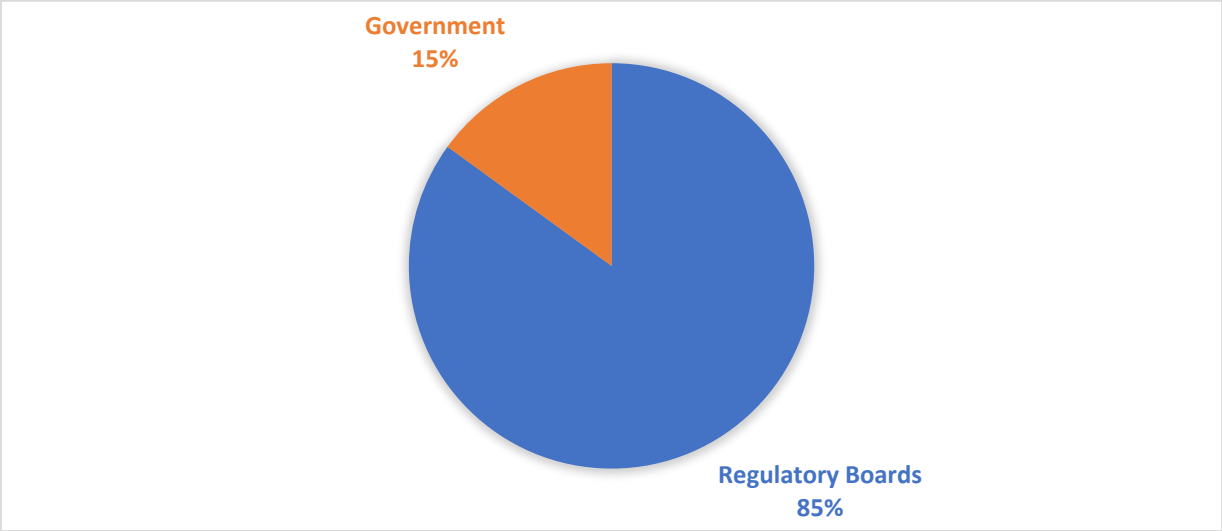


Figure 17 Responsibility on the formulation of Policy

85% of respondents reported that Regulatory boards are responsible for formulation of policy. Attributed to the fact that they are better acquainted to the industry and they understand Building Information Modelling use in the industry and applications. Again, drawing similarities to the Netherlands where construction industry stakeholders pushed Building Information Modelling adoption which led to the formulation of policy.

Only **15%** of respondents thought Government should formulate policy

3.18. Alternative ways to increase BIM adoption.

In order to increase and encourage the adoption of Building Information Modelling the following were suggested:

1) Inculcate it in the Engineering curriculum.
2) Promoting the use of Building Information Modelling applications by all professions within the built environment by
   - Encouraging of partnerships between software vendors and organizations to increase awareness.
   - Recognizing of Building Information Modelling awareness as a source of Professional Development Unit points by Architectural and Engineering regulatory bodies.
3) Creating awareness through workshops, conferences and including Building Information Modelling training in the curriculum of tertiary institutions.
4) Make it cheaper and accessible.

Conclusion

Based on the findings of the study the uptake of Building Information Modelling is quite average despite the high level of awareness on Building Information Modelling and its benefits to the design process.

The main design processes where Building Information Modelling is used are structural analysis and design documentation. The processes with average use are conceptualization of design and design interpretation. The processes where Building Information Modelling is least used for are clash detection, estimation of quantities, submission to relevant authorities, archiving of information scheduling of work and trade coordination. Despite this, there was a low level of application across all the processes. Indicative of an underutilization of Building Information Modelling in the processes.

The main hinderances to Building Information Modelling adoption are cost of the software, lack of awareness and lack of trained personnel. Lack of Policy, Incompatibility with existing structures, cost of setting up additional systems and lack of incentives for use were considered minor factors by the respondents.

Recommendations

On the basis that Building Information Modelling adoption is necessary the following are recommended:

a) Building Information Modelling should be made part of the Construction Industry curriculums. Thus, enhancing the training of industry professionals to be better equipped to join and contribute efficiently to the market.
b) Encourage further research into Building Information Modelling in Kenya and the continent of Africa.
c) Creating and increase awareness to all industry stakeholders on the importance of its adoption.
d) Introduction of Government Building Information Modelling strategies and policies in the Construction Industry Development Policy of Kenya that would see a guided and uniform adoption of Building Information Modelling.
e) Specifying Building Information Modelling use on governments project as was done in the USA by the GSA unit.
f) Make it cheaper and accessible through reducing the taxes charged on Building Information Modelling software.

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