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IMPACT OF BUILDING INFORMATION MODELING ON PROJECT OVERRUNS IN NAIROBI AEC FIRMS

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ABSTRACT

In Africa the number of required housing units is estimated at 4,000,000 units per year 60% of the demand being in the urban areas. In Kenya the total cost of stalled projects like affordable housing and roads is about 9 trillion. The purpose for this research was to seek the impact BIM could play in mitigation of these incomplete projects. The specific objectives of this research are to determine; the scale of usage of entire spectrum of BIM dimensions and its' influence in preventing cost and time overruns in Nairobi county. Questionnaires and oral interviews were used to collect data from 237 professionals in the built environment and 30 firms in AEC Nairobi County. The data from questionnaires was coded in SPSS and analyzed statistically while the oral interviews were analyzed thematically. The study found out that there was a statistically significant difference in both cost and time for projects done pre-BIM adoption compared to projects undertaken post-BIM adoption. The research also found that most AEC firms have only evolved to level 1BIM. More awareness needs to be created on the benefits BIM can offer as well as the need to employ knowledgeable professionals for its successful implementation. However, the benefits of employing the entire spectrum of BIM must be carefully considered against the size of projects.

KEYWORDS: Building Information modeling, Maturity, Architectural engineering and construction (AEC), Board of Registration of Architects and Quantity Surveyors (BORAQS), Continuous professional development (CPD), Strength Weakness Opportunity and Threats (SWOT).

1.0.INTRODUCTION

A report by World Bank in 2013 indicates that housing needs of about 2.7 billion people have to be met. This surge in population is likely to be witnessed between 2013 and 2050. This occurrence is mainly necessitated by rural-urban migration as migrants seek better employment opportunities, seeking of services that are unavailable in rural areas and generally seeking to improve their livelihood (World Bank, 2013). In Africa the number of required housing units is estimated at 4,000,000 units per year having more than 60% of the demand being needed to accommodate people living in urban areas (UN-HABITAT, 2008). In the Kenyan context a population report of 2016 shows that 12million people, representing 31% of the total population was living in urban areas. This population in the urban areas is projected to reach nearly 46% by 2030 (UN News, 2018).

With increase in new construction projects, complex nature of the construction industry, development of more complex buildings, new construction techniques and larger scale of housing developments construction projects have become more complex and harder to manage (Alshawi Issa, 2003). It is very vital to take note that most developing countries are headed in the direction of industrializing their countries. The role construction industries play in industrialization is very pivotal in achieving the dreams' of these nations (Alaghbari et al., 2001). Unfortunately, these dreams are hindered by a construction scene that is filled with incomplete projects, projects being delivered that are substandard and projects that have huge variations from the predetermined sum and time. It is against this back drop that has seen emergence of technologies geared towards curbing the aforementioned problems (Abd & Akhund, 2017). Building information modelling BIM is one such technology which has overtime gained global acceptance as being able to solve most problems in the construction industry. BIM is a cloud based process supported by various tools, technologies and contracts involving the generation and management of 3D models in a virtual environment (Succar, 2009). Some of the tools that support BIM include Revit which is software that is used to adjust Architectural, structural, landscaping, Mechanical, Electrical and plumbing models as and when needed during the design phase through to the construction of the building. BIM is also supported by Navis works which assists in scheduling of activities through the construction phase. Another support tool in BIM is assemble this is a tool that help in quick generation of estimates from dimensions in Revit (Zhang, 2012). BIM has become an ingenious tool that if used well has the potential to improved how projects are procured, constructed, facility management and maintenance (Xiao & Noble, 2016). According to a study done out of 359 projects in Malaysia only a paltry 30% were completed within the project budget (Asmi et al., 2013). He recommended that the situation needs to improve by critically analyzing why 70% projects failed to meet the predetermined cost estimates. In Kenya the total cost of stalled projects like office blocks, affordable housing units, dams and roads is about 9trillion. This is a worrying trend as it majorly indicates that there is no adherence to project guidelines issued by the regulatory agencies (Ngacho & Das, 2013). According to the Project management institute, lack of communication in construction industry accounts for 30% of project failures. It is approximated that for every one billion USD set aside to be used in a project 135 million is at risk of being lost. The study further shows that 56% of the 135 million USD is at a risk of being lost because of ineffective communication practices (PMI, 2008). BIM if used well is an indispensable tool as far as smooth project delivery is concerned. It not only allows for smooth flow of up to date of information but also plays a key role in sustainable construction say if professionals work fluidly whilst collaborating teams would brainstorm on choice of HVAC equipment to arrive at a sustainable design and equipment choice (Bryde et al., 2013). Developers who rent out unfinished housing flats not only violate Kenya's building code but also put tenants at a risk of health and physical hazards (Fashina et al., 2020).

Areas like Eastleigh, Nairobi's eastlands, Dagoretti and along Thika road have steel protruding from slabs yet the developers still harbor plans of adding more floors on the already fragile structures. Not only are such projects structurally unfit but also do not follow laws regarding the building code (Olingo et al., 2010). This clearly illustrates the need for cost and time planning for projects from inception through to construction phases to avoid such matters. The purpose of this study was to get insight on the extent Building information modeling could assist in mitigating cost and time overruns in middle income housing, to assess the level of BIM maturity in AEC firms within Nairobi County and to develop a strategic roadmap aimed at increasing BIM adoption.

2.0 RESEARCH DESIGN AND METHODS

2.1 Sampling and analysis of data from construction firms

The data collection procedure that was adopted in this study involved; pilot study, pre-study sessions and finally the actual administering of the research instruments. When all the necessary adjustments were made, permission was sought from various AEC firms in Nairobi. Below is the criteria used to gather the number of firms that were required to participate in the survey.

Primary data was obtained through administration of structured interview questions to a sample size of 23 construction firms in Nairobi County which was obtained mathematically; Nassiuma *et al*; (2002):

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where; n is the sample size being sort

N is the total population

C is the coefficient of variation of which 30% is ok

e is the relative standard error where 5% is accepted

$$Therefore; n = \frac{135 X O.3^2}{0.3^2 + (135-1) X\, 0.05^2} = 28.59$$

This survey comprised 23 respondents out of the targeted 30; this was 76.7% of the projected sample size which was used in subsequent analysis. A response rate of 75% is the minimum for sufficient analysis Creswell (2014). Data collection in each of the selected firms was done for projects undertaken pre-BIM and those after BIM adoption. Specific areas of interest were the original tendered sum of the projects, the final account, the initial agreed completion period and the actual completion period of the projects.

The interview recorded causes of variation between tendered sum and final account. The variation between the initial agreed completion period and the actual completion period of the projects and the time and cost variations were recorded as percentages of their tendered sums and the initial project completion periods respectively. In cases where the Firm had adopted BIM since its inception, the tendered sums, the final account and the causes of variation that existed, were recorded (Tables 2 and 3).

The responses obtained were used in coming up with an inference of influence BIM has had if any on the costs and time of these projects. For absolute confidentiality the specific name of the projects done by the firm were not be quoted. This method compares favorably with that of (Kristen, 2012) who undertook a study seeking to know how BIM has improved cost performance overtime by comparing costs of building undertaken during the 2D era and the cost of buildings undertaken during the 3D era.

2.2 Sampling and analysis of data from construction industry professionals

The second part of the study entailed seeking views from members of the following professional bodies practicing in Nairobi; Board of registration for Architects and quantity surveyors and Engineers board of Kenya. Architects practicing countrywide -1066 Registered Quantity Surveyors countrywide – 684 Engineers board of Kenya- total number of Engineers registered – 2336. Our study assumption was that approximately 70% of professionals would be practicing in the capital city, therefore the Chrocan formula was used to determine the actual numbers. Sample size for this analysis was determined by *Chrocan formula.*

$$n_0 = \frac{Z^2 p(1-p)}{e^2}$$

$$n = \frac{n_o}{1 + \frac{n_o - 1}{N}}$$

n_o *Chrocan sample size recommendation*

N *Population size*

n *new adjusted sample size*

Using the above formula, a total of 256 professionals were targeted for the study; however, the actual number that responded was 237 as follows; Architects-70, Quantity surveyors-75, and Engineers and construction managers-92.

2.3. Sampling technique

The procedure used for this study was non-probability convenient sampling as it offered more data that could be acquired easily and which would have little bias since the study targeted professionals.

2.4. Pilot study

Questionnaires and oral interviews were administered using a cross sectional survey approach. To achieve validity, of the research instrument experts in the construction field at the Ministry of public works and contractors near Jomo Kenyatta University of Agriculture and technology were asked to make comments where necessary on the research instrument and check if they measured the study objectives and variables under study exhaustively. All the 29 respondents involved in the pilot study approved the research tool as being able to cover the study well.

2.5. Determination of BIM Maturity in Nairobi AEC Firms

In order to determine extent of incorporating BIM on cost planning at the inception phase of a project, the 237 respondents were asked the extent to which they experienced challenges in the absence of BIM services; with regards to the following variables; cost control, abortive works, dispute resolution, cost planning, cost overruns and time overruns. These questions were aimed at revealing the project professionals' perception of elements of cost and time whilst using BIM and the various implications of failure to cost and time plan. The professionals were expected to know cost planning concepts and display an awareness of the procedures. The results were analyzed using the Shapiro-wilk test of normality hence use of spearman's correlation in determining to what extent these variables were dependent on BIM being employed.

2.6. Determination of BIM Diffusion areas in Nairobi AEC firms

According to (Succar, 2010) the 3 stage capability model helps identify level of BIM maturity of a given region. The three stages are; evaluating modeling diffusion areas, BIM macro maturity variables and finally identifying drivers of BIM. These were done using a 5-point likert scale. The extent of diffusion modeling technologies, collaboration, policies and integration was determined. To establish macro-maturity components, model 8 complementary components were used in measuring and establishing BIM maturity of Nairobi AEC firms. The components analyzed were; whether the organizations have objectives with regards to BIM use, whether there were noteworthy publications that are BIM related? Whether there were set standards with regards to education and training BIM, whether there were any BIM regulatory frameworks in place, whether there were BIM technology infrastructure in place, whether there were BIM champions in place, whether there were measurements and benchmarks in place and finally were there any standards in place.

2.7. Thematic analysis to create roadmap to BIM implementation

Thematic analysis was used to analyze this objective according to (Brown and Clarke 2006), the analysis entailed the following; searching across data-sets that have been identified, analyzed and repeated patterns reported. The specific type of thematic analysis that was employed was deductive approach where questionnaires were sent out to respondents based on the 3 major themes; policies, technologies and processes which are the major underpinnings of BIM adoption. The subtext and assumptions of underlying data were factored in during the analysis. The following were the major steps done in the thematic analysis; Data familiarization, coding, grouping codes into categories and finally the various responses were categorized accordingly and presented in form of a flow chart using the lucid chart *https://lucid.app/documents#/documents?folder_id=home*. Table 1 shows an excerpt of the coding procedures undertaken.

Table 1: Example of coded responses from professionals.

Feedback excerpt	Codes
'In my view we are lagging behind in terms of fully integrating our construction steps digitally. We are deficient in terms of how design teams deliver documents. We don't have standardized methods of how we deliver construction information. It is for this reason that we need to have standardized ways of how we work, communicate among project teams and I feel this can only start from top government who can regularize the construction scene. We also need to have more robust trainings that are BIM related. Finally, it should be noted that BIM move would be very difficult if members in AEC are unaware of the benefits BIM accrues to firms'	• Lagging behind digitally • Deficient in design team communication • No standardized methods of operation • Need for standardized forms of communication • Top government to create laws governing BIM • Robust trainings • Creation of awareness of BIM • Benefits of BIM to firms

3.0 RESULTS AND DISCUSSION

3.1 Cost and time completion rates for pre and post BIM eras.

The original tendered sum of the projects, the final account, the initial agreed completion period and the actual completion period of the projects showed the highest cost from the 23 sampled firms was 1.17Billion Kenya while the lowest was 6.2 million Kenya shillings. The projects were predominantly residential apartments built for the middle-income Kenyans. For most firms the time it took to undertake their projects during the surveyed periods was about 1year and 9 months (table 2 and 3).

Table 2: Cost and time completion rates pre-BIM era.

Firms Interviewed	Bq Sum	Final Account	Variation	Start Time	Actual Time	Time Variation
Hall mark enterprises	17.53	18.13	3.40	1.00	1.20	20.00
Student hostels	126.43	139.82	10.60	2.00	2.80	40.00
	262.15	291.15	11.10	2.50	3.00	20.00
Master cost	170.10	198.00	16.40	1.00	1.60	60.00
Apartment blocks	21.46	24.80	15.60	0.90	1.60	77.80
	250.30	310.00	23.90	3.00	3.80	26.70
	136.00	157.00	15.40	2.50	2.90	16.00
KRK Associates	47.80	58.80	23.00	1.10	1.30	18.20
Apartment blocks	9.30	8.20	-11.83	0.50	0.65	30.00
	82.80	61.50	-25.72	2.50	3.30	32.00
Ngugi.K. Associates	48.07	57.96	20.57	0.50	0.40	-20.00
Apartment blocks	69.18	84.17	21.67	1.10	1.40	27.30
	127.47	145.71	14.31	2.00	2.20	10.00
Shelter cost consultants	232.11	312.23	34.52	1.50	2.00	33.30
Apartment blocks	14.30	17.24	20.56	0.60	0.70	16.70
	78.67	94.86	20.58	1.10	1.60	45.45
	162.50	163.00	0.31	0.80	1.00	25.00
Cost plan QS Ltd	96.42	118.64	23.05	3.00	3.20	6.67
Apartment blocks	176.30	181.14	2.75	2.00	2.30	15.00
	212.64	263.54	23.94	3.00	3.50	16.67
	56.55	57.03	0.85	1.00	1.15	15.00
GRE-DCO Developers	8.71	9.01	3.44	0.70	0.80	14.30
	6.59	8.53	29.44	0.90	1.30	44.40
HARRE Construction Ltd	87.43	92.48	5.78	1.60	1.80	12.50
	197.18	208.63	5.81	2.00	2.40	20.00
	46.78	52.56	12.36	1.50	1.70	13.30
ANM Consultants	46.83	59.12	26.24	1.60	1.80	12.50

	784.50	872.47	11.21	4.00	4.30	7.50
	462.45	477.35	3.22	2.50	2.80	12.00
	342.22	361.57	5.65	3.00	3.40	13.30
Volcanic works	68.67	71.58	4.24	1.00	1.50	50.00
	84.57	91.89	8.66	1.80	2.80	55.60
Shequa associates	45.96	48.10	4.65	0.80	1.40	75.00
	58.50	65.80	12.48	1.00	1.20	20.00
	78.57	90.57	15.27	2.00	2.90	45.00
Mucheki & Sons	50.50	50.90	0.79	1.10	1.50	36.00

Table 2. Continued Cost & time completion rates Pre-BIM Era

Firms Interviewed	Bq Sum	Final Account	Variation	Start Time	Actual Time	Time Variation
Emjay consultants	78.98	87.92	11.32	1.50	1.70	13.30
	150.00	148.00	-1.33	1.80	2.00	11.10
BECS consultants	315.00	318.00	0.95	1.60	1.70	6.20
Affordable housing	1170.00	1500.00	28.21	1.00	1.80	80.00
	14.50	19.50	34.48	0.20	0.25	25.00
Mwatha Architects	253.10	265.36	4.84	2.20	2.60	18.18
	65.20	75.78	16.23	2.50	2.70	8.00
Marimo construction	40.31	40.82	1.27	0.80	1.20	50.00
	599.89	600.35	0.08	2.50	2.70	8.00
Ministry of public works	78.50	80.50	2.55	0.70	1.00	42.86
	127.00	130.00	2.36	1.50	1.60	6.67
	45.00	64.80	44.00	2.10	2.30	9.52
Jeiel consult	6.20	6.50	4.84	0.50	0.50	0.00
	13.50	14.00	3.70	0.70	0.80	14.29
Judiciary of Kenya	94.16	96.00	1.95	3.00	3.40	13.33
	158.50	163.00	2.84	0.90	1.20	33.33
Rama homes Ltd	434.57	440.12	1.28	1.10	1.80	63.64
	235.50	238.50	1.27	1.50	1.70	13.33
Oje associates	232.50	245.16	5.45	2.20	2.50	13.64
	34.00	33.45	-1.62	0.70	0.60	-14.29
Mathu & Gichuiri						
Associates	304.00	324.67	6.80	3.00	3.50	16.67
	74.80	76.50	2.27	2.00	2.30	15.00
QS. Karanja	22.30	23.50	5.38	0.80	1.00	25.00
	45.60	40.30	-11.62	2.00	2.20	10.00

Table 3: Cost and time completion rates post-BIM era.

Firms Interviewed	Bq Sum	Final Account	Variation	Start Time	Actual Time	Time Variation
Hall mark enterprises	71.04	89.71	26.28	1	1.3	30
	19.36	24.63	27.22	0.7	1	42.86
	186.53	191.04	2.42	2.5	3	20
Master cost	13	12.7	-2.31	0.9	0.9	0
	340	361	6.18	3	3.2	6.67
	68	72	5.88	1.3	1.5	15.38
	56	58	3.57	0.8	1	25
KRK Associates	80.5	85.5	6.21	4	5	25
	121.5	130.7	7.57	2.2	2.3	4.55
Ngugi.K. Associates	65.28	69.5	6.46	0.5	0.6	20
	82.38	88.46	7.38	1.1	1.4	27.27
Shelter cost consultants	182.46	176.29	-3.38	3	3.2	6.67
	346.29	358.14	3.42	1.5	1.8	20
	432.44	512.5	18.51	2.8	3	7.14
Cost plan QS Ltd	99.46	112.46	13.07	0.9	1.1	22.22
	42.61	45.29	6.29	1.5	2.2	46.67
	321.4	329.142	2.41	3	2.8	-6.67
	723.49	767.5	6.08	2.8	3	7.14
GRE-DCO Developers	64	69	7.81	1	1.3	30
	33.26	37.13	11.64	0.5	0.67	34
	22.64	25.16	11.13	0.7	0.8	14.29
HARRE Construction Ltd	233.33	241.7	3.59	5	5.5	10
	98.68	100.3	1.64	1	1.2	20
ANM Consultants	482.27	510.61	5.88	3	3.2	6.67
	112.48	117.36	4.34	2	2.5	25
Volcanic works	842.35	868.7	3.13	4	4.5	12.5
	548.26	572.809	4.48	2	2.3	15
Shequa associates	86.48	88.68	2.54	2	2	0
	18.42	19.54	6.08	0.6	0.7	16.67
Mucheki &	75.8	77.3	1.98	2	2.1	5

Sons						
	20.2	21.8	7.92	0.4	0.45	12.5

Table 3: Continued Cost and time completion rates post-BIM era.

Firms Interviewed	Bq Sum	Final Account	Variation	Start Time	Actual Time	Time Variation
Emjay consultants	256.49	278.58	8.61	4	4.1	2.5
	84.29	85.13	1	2.2	2.1	-4.55
BECS consultants	56.5	58.8	4.07	0.8	1.3	62.5
	480.2	481.3	0.23	2.7	2.8	3.7
Mwatha Architects	89.5	91.2	1.9	1.1	1.05	-4.55
	125.8	133.9	6.44	3	3.3	10
Marimo construction	40.4	44.2	9.41	0.8	1	25
	527.8	560.5	6.2	1.5	1.8	20
Ministry of public works	672.8	687.8	2.23	2.2	2.4	9.09
	25.5	27.2	6.67	0.7	0.75	7.14
Jeiel consult	102.5	101.7	-0.78	2.5	2.9	16
	56.9	65.2	14.59	1.1	1.45	31.82
Judiciary of Kenya	235.5	238.2	1.15	3	3.6	20
	123.5	130.9	5.99	1.2	1.3	8.33
Rama homes Ltd	450.6	465.8	3.37	2.7	3	11.11
	280.7	310.2	10.51	1.2	1.5	25
Cytonn limited	357.6	356.44	-0.32	2.1	2.2	4.76
Mathu & Gichuiri						
Associates	30	31	3.33	0.8	0.8	0
	114.97	122.8	6.81	1.5	1.65	10
QS. Karanja	42	43.5	3.57	0.8	1	25
	24.5	26.7	8.98	0.7	0.8	14.29

3.2 Analysis of Time variation pre and post BIM eras

From the firms and professions that were surveyed in Nairobi (Tables 2 and 3), analysis of time variances using T-test for unequal variances showed there was a significant difference in the time it took to undertake projects between the two different eras since a test statistic of -2.5977 was obtained which falls in the rejection region when using the t-critical point of -1.9870. The results showed a P-value of 0.0109 which was less than alpha of 0.05 hence the null hypothesis that there had been no time difference in the percentage of means of time variation before firms employed BIM and when they employed BIM in their practices was rejected. The results indicate that on average projects that were undertaken during the Pre-BIM era had a time variation of 24.48% and this has since reduced to 15.74% during the era where BIM has started being used by firms in Nairobi County (Table 4).

Table 4: T-test analysis of Time variation pre and post BIM eras.

	% In time variation Post BIM	*% In time variation Pre BIM*
Mean	15.744	24.476
Variance	179.213	408.313
Observations	52	52
Hypothesized Mean Diff	0	
df	89	
t Stat	-2.598	
P(T<=t) one-tail	0.005	
t Critical one-tail	1.662	
P(T<=t) two-tail	0.011	
t Critical two-tail	1.987	

Null Hypothesis; that there is no time difference when BIM is employed in either the Pre-BIM era or the post-BIM era. $\mu_{1-}\ \mu_2=0$

Alternate hypothesis; that there is a recorded difference in time between pre-BIM era and the current era where firms are employing BIM. $\mu_{1-}\ \mu_2 \neq 0$

3.3 Analysis of Cost variation pre and post BIM eras

The analysis of cost variances of the firms using T-test for unequal variances, showed that there was a significant difference in the costs it took to undertake projects between the two different eras. A test statistic of +2.421 was obtained which falls in the rejection region when using the t-critical point of -1.9934. Comparison of the P and alpha values, showed a P-value of 0.0179 which was less than alpha of 0.05 hence the null hypothesis that there had been no cost difference in the percentage of means of cost variation before firms employed BIM and when they employed BIM in their practices was rejected (Table 5).

Table 5: T-test analysis of Cost variation pre and post BIM eras.

	% In cost variation Post BIM	*% In cost variation Post BIM*
Mean	10.80588664	6.141763359
Variance	158.7905769	34.19290837
Observations	52	52
Hypothesized Mean Diff	0	
df	72	
t Stat	2.421093826	
P(T<=t) one-tail	0.008997921	
t Critical one-tail	1.666293696	
P(T<=t) two-tail	0.017995843	
t Critical two-tail	1.993463567	

3.4 BIM maturity and professionals' perceptions

According to the respondents, cost overruns that would be occasioned by failure to use BIM had a significant effect of +0.375 when correlated with dispute resolution hence cost overruns would likely lead to arising of disputes. Most respondents also felt that Failure to cost plan that was occasioned by not using BIM had a significant effect on projects that faced cost overruns with a correlation of +0.509 hence failure to cost plan was likely to lead to cost overruns. When cost overruns were correlated with instances of time overruns on site when BIM was not being employed it was found out that there was a high significance between the two variables because they had a value of +0.698 hence either cost overruns or time overruns would come up when BIM isn't being employed (Table 6).

Table 6: Spearman's Inter-variable Correlation Matrix.

		Cost control	Abortive work	Dispute resolution	Cost planning	Cost overruns	Time overruns
Cost control	Pearson Correlation	1	.345**	.282**	.567**	.424**	.325**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	237	237	237	237	237	237
Abortive work	Pearson Correlation	.345**	1	.478**	.339**	.365**	.357**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	237	237	237	237	237	237
Dispute resolution	Pearson Correlation	.282**	.478**	1	.400**	.375**	.440**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	237	237	237	237	237	237
Cost planning	Pearson Correlation	.567**	.339**	.400**	1	.509**	.395**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	237	237	237	237	237	237
Cost overruns	Pearson Correlation	.424**	.365**	.375**	.509**	1	.698**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	237	237	237	237	237	237
Time overruns	Pearson Correlation	.325**	.357**	.440**	.395**	.698**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	237	237	237	237	237	237

**. Correlation is significant at the 0.01 level (2-tailed).

3.5 Succar's 3 stage maturity model

Modeling technologies used by AEC firms had the highest maturity at 34% when compared to other diffusion elements, these puts Nairobi firms at medium low technology wise since

BIM aspects like integration, collaboration using common data environments had not been at the core in the digitization of construction industry during CAD evolution**.** Collaboration had a score of 17%, Integration scored very lowly at 9% as there are no strategies in firms to have common data environments as shown in Figure 1. According to the respondents there seems to be no policies in place in relation to BIM use, adoption or any technology it is a free field. Respondents who choose that there were policies in place were only 3%.

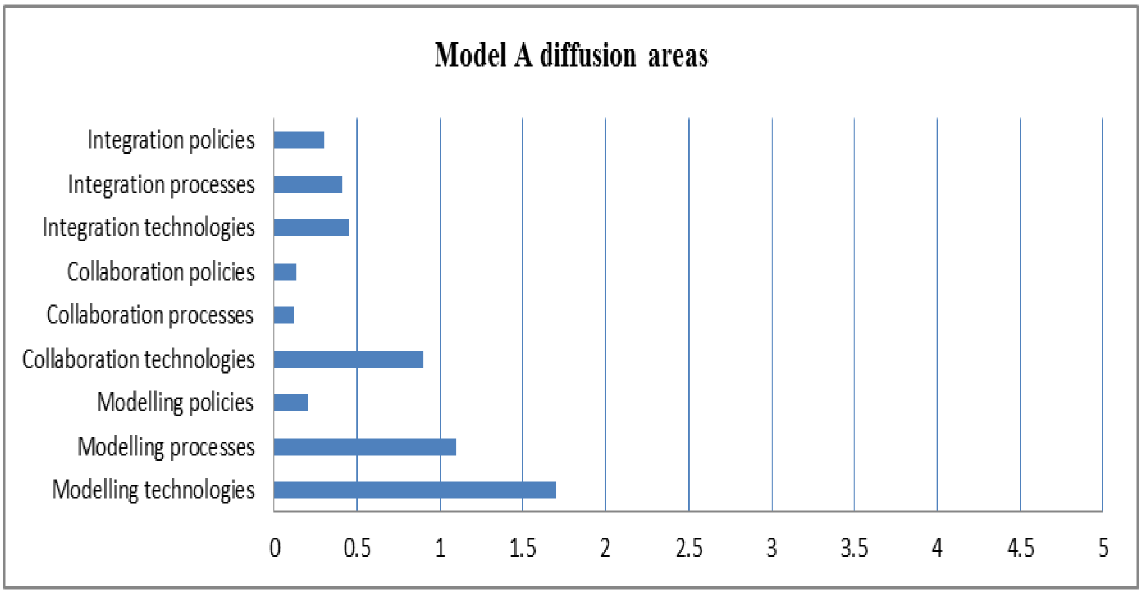

Figure 1: Diffusion rates of modeling, collaboration and Integration aspects.

3.6 Determination of BIM macro-maturity variables

Most respondents scored between level 1 and 2 which were initial and managed respectively this is much lower than the 5 point score which shows full optimization. Regulatory framework and champions of BIM ranked lowest, indicating two major issues, the first is that there has not been government effort with regards to BIM use and policies and secondly organizations have not taken BIM seriously. To ensure that events are well collaborated and integrated the appointment and training of BIM managers is positively related to the level of maturity. Technological infrastructure ranked highest with an average maturity of 2.3 as shown in figure 2. Indicating that AEC firms are capable of adopting these BIM technologies. The only challenge that arose is that such firms didn't have any objectives and strategies in place to give a clear pathway of how they would like to delve further into the full BIM spectrum.

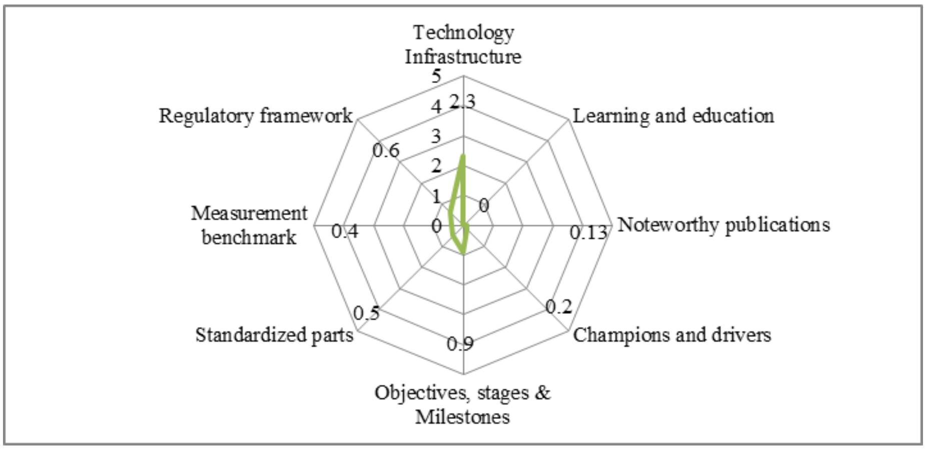

Figure 2: BIM macro-maturity variables.

3.7. Drivers of BIM technologies in Nairobi AEC firms

The diffusion dynamics were mainly driven by large firms.77% of the respondents felt that the diffusion dynamic in Nairobi AEC firms was middle-out, while 19% argued it was bottom-up, and only 7% stated it was top-down as shown in table 7. Therefore, Nairobi diffusion dynamic is middle out. Contractors and firms in large AEC firms started the move to BIM through supply of 2D information so as to deliver value to themselves and to their clients. The effect this has had on smaller firms is that it has forced or exerted pressure on smaller firms that receive subcontracts to adopt aspects of BIM such as 3D modeling.

Table 7: Drivers of BIM technologies in Nairobi AEC firms.

Mechanism	Institutional actor	Pressures	Potential adoption model
Top down	Government or regulatory body	Downwards	All actors are under the influence of the authority exerting pressure
		Horizontal	Government and authorities in other markets
Middle out	**Large organization or industry association**	**Downwards**	**Other companies in the supply chain**
		Upwards	Government or regulatory bodies in the same market
		Horizontal	Other large companies
Bottom up	Small firm	Upwards	Large companies or industry associations
		Horizontal	Other small firms

3.8. Thematic analysis of Pre and post BIM dynamics among Nairobi AEC professionals

Analysis of professional responses was summarized thematically and a schematic representation was done as shown on figure 3 below. The current BIM level was attributed to the following; most professionals were unable to quantify the benefits BIM accrued to them, small firms were not able to afford some of these technologies, resistance from those who grew up the profession without BIM, Insufficient investment in companies training their staff and finally even those that have agreed to the BIM move face interoperability challenges as different firms employ these technologies differently.

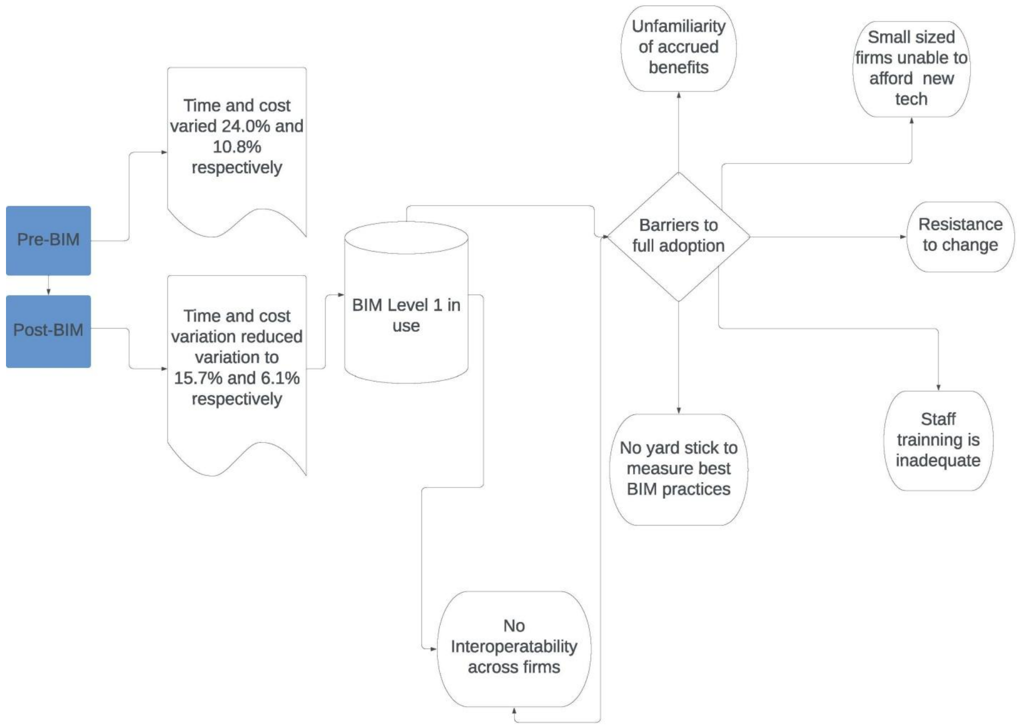

Figure 3: Pre and post BIM driving forces among Nairobi AEC professionals.

3.9. Strategic road map to increase BIM adoption

The Lucid chart was formed based on 29 major themes that were coded from the respondents. Figure 4 shows the flowchart explaining the workflow system development proposed by the various AEC professionals for the increased uptake of BIM. The flowchart includes three main aspects in BIM implementation, namely, policy, processes and technologies aspects. In the policy aspect most it was felt that professional bodies like board of registration of Architects and Quantity surveyors (BORAQS) need to be at the forefront in lobbying for enactment of legislation requiring BIM use. Respondents also reported that Government had to be part of the process by first starting to adopt BIM technologies in all of its' projects from tender to final completion. This would push any firms doing business with government to increase their full BIM adoption. The study found that for process aspects to work seamlessly it is more of an internal issue requiring management team to identify strengths, weaknesses, opportunities and threats they face, appointment of BIM champions and having clear organization guidelines on BIM implementation. Finally in the process field it was found that organizations need to take that bold steps and put more investment in software purchase and leverage on BIM technologies to boost their performance. Some of the ways proposed to boost technical and process aspects were; students in secondary schools need more exposure on IT, more modules need to be introduced in Universities that focus on BIM technologies, more awareness needs to be created by professional bodies on BIM benefits and continuous training and development at work to get the latest on BIM developments.

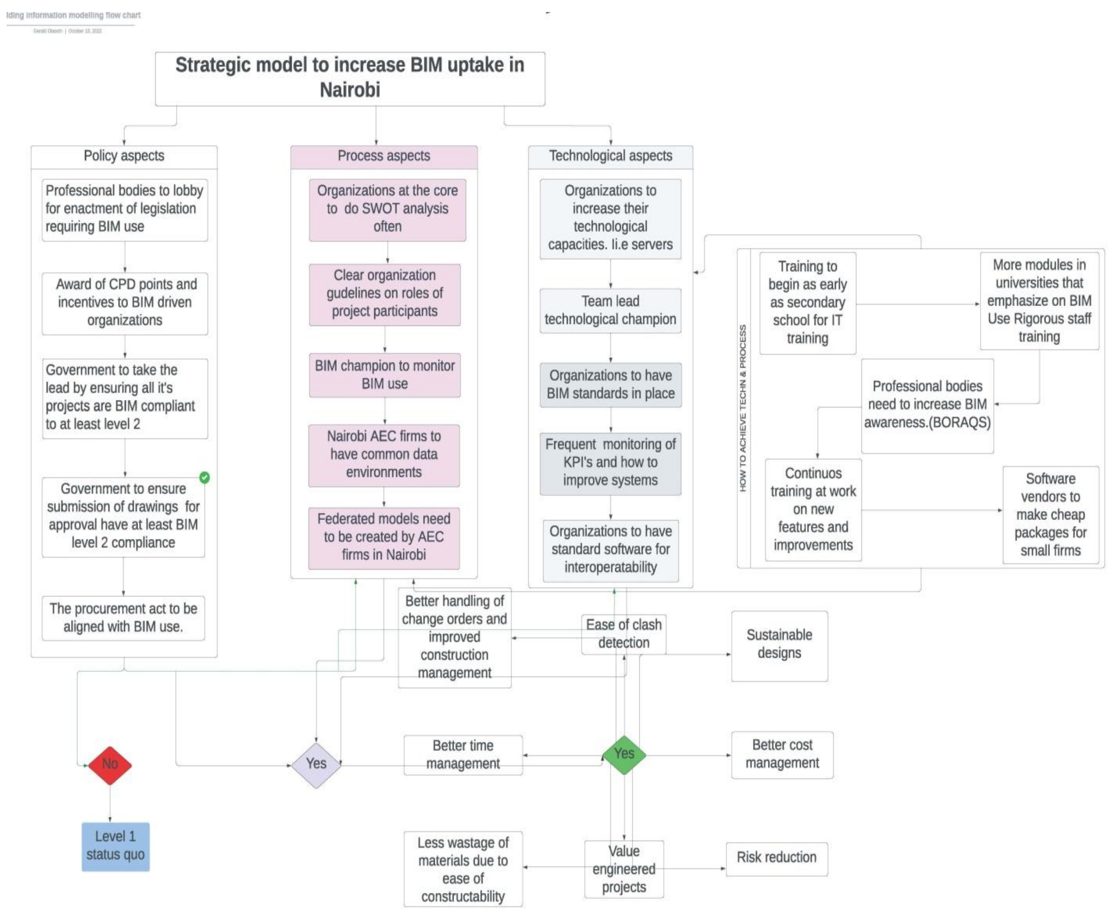

Figure 4: Strategic Road map to increase BIM adoption.

4.0 General Discussion

The purpose of this investigation was to examine the influence of building information modeling on cost and time overruns and to determine the entire scale of usage of BIM dimensions in middle income housing Nairobi County. The Level of BIM usage among AEC firms in Nairobi County was found to be at its infancy stages with only a few firms seeming to be ahead of the pack with high technological capabilities. This shows that most firms have only scratched the surface of the capabilities BIM has to offer. This study concurs with some of the recommendations of the study undertaken by (Mbarga & Mpele, 2019) in Cameron showed that although BIM had started getting traction in 2017 most schools had not embraced any training that is BIM related. Any form of Software training was undertaken as a separate package for those who had a keen interest in expanding their knowledge digitally. Some of the recommendations given by professionals in our study were; IT skills be taught as early as secondary education and redesigning of the current university curriculum to have more BIM related modules. Given the kind of adoption of BIM among Nairobi AEC firms it is not surprising that the change in cost performance between Pre-BIM usage and Post-BIM usage was evident with many firms reporting how project teams visualized 3D images has been a major improvement from 2D views as some details could easily be left out during design or construction. This would later impact aspects like cost as inability to properly visualize during tendering stages would likely lead to projects that do not meet their cost and time targets. According to analysis performed in this study there has been a significant improvement in both cost and time overruns over the time BIM has slowly started gaining traction. According to J.C. (Cannistrato, 2009) a Plumbing, HVAC, and Fire Contractor in the Massachusetts area, where their survey utilized data from 408 projects over a 6 year period totaling $558,858,574 to quantify savings from using BIM. The cost reduction due to change orders for “2D” projects represented 18.42 percent of base contract, change orders for “3D” projects represented 11.17 percent of base contract, and change orders for “Collaborative BIM” projects represented 2.68 percent of base contract. This compares favorably with our study in which we found that variation due to time and cost had a reduction of 9% and 4% respectively. However it is important to note that BIM is pegged on aspects of visualization, quantification, communication, coordination and simulation. When one piece of this puzzle is not being utilized like in our construction scene we can see the scoring pattern of the elements of communication and coordination have performed poorly with regards to BIM in construction.

Our study isolated some of the reasons of how BIM has helped firms achieve their cost and time targets initially set out were; minimized human error, reduced cases of overdesigned structures, the aspect of 3D viewing greatly improved constructability, enhanced data storage. Some professionals however were of the opinion that construction professionals should not be overly optimistic of the advantages BIM would accrue a firm as this is a system relying on data fed to it hence having personnel that aren’t knowledgeable in their fields would still occasion cost and time overruns. The prevailing economic conditions with the emergence of Covid and political instability will still likely be a contributor to cost and time overruns, firms not willing to fully immerse themselves into adopting BIM would in the long run erode the gains of those already using BIM. How are these gains eroded? Because BIM relies on interoperability when different firms are required to work on a project, when one of the firm is lagging in terms of BIM compliance challenges of communication and coordination will always crop up as these are among the major problems BIM is meant to deal with. Maturity level 1 is still far from best practices in BIM.

5.0. Conclusions and Recommendations

Building information modeling was found to have a big impact on project overruns in Nairobi County. BIM in Kenya is not a new concept to AEC professionals and construction firms however its' use has only scratched the surface of BIM's depth It is therefore important for firms and project professionals to agree to the digital move when managing projects. Institutions like BORAQS, AAK ought to give recommendations to government stakeholders to create laws that would require engagement of a certain minimum level of BIM in all projects especially those of a big nature so as to try and curb this worrying trend to a certain degree. There is also the need to create awareness to all construction industry players on the essence of cost planning, cost controlling, time planning whilst using BIM to manage this project factors.

Data Availability

Data for this research article are available upon request to the corresponding author.

Conflicts of Interest

The authors of this paper declare that there is no conflict of interest regarding the publication of this paper.

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