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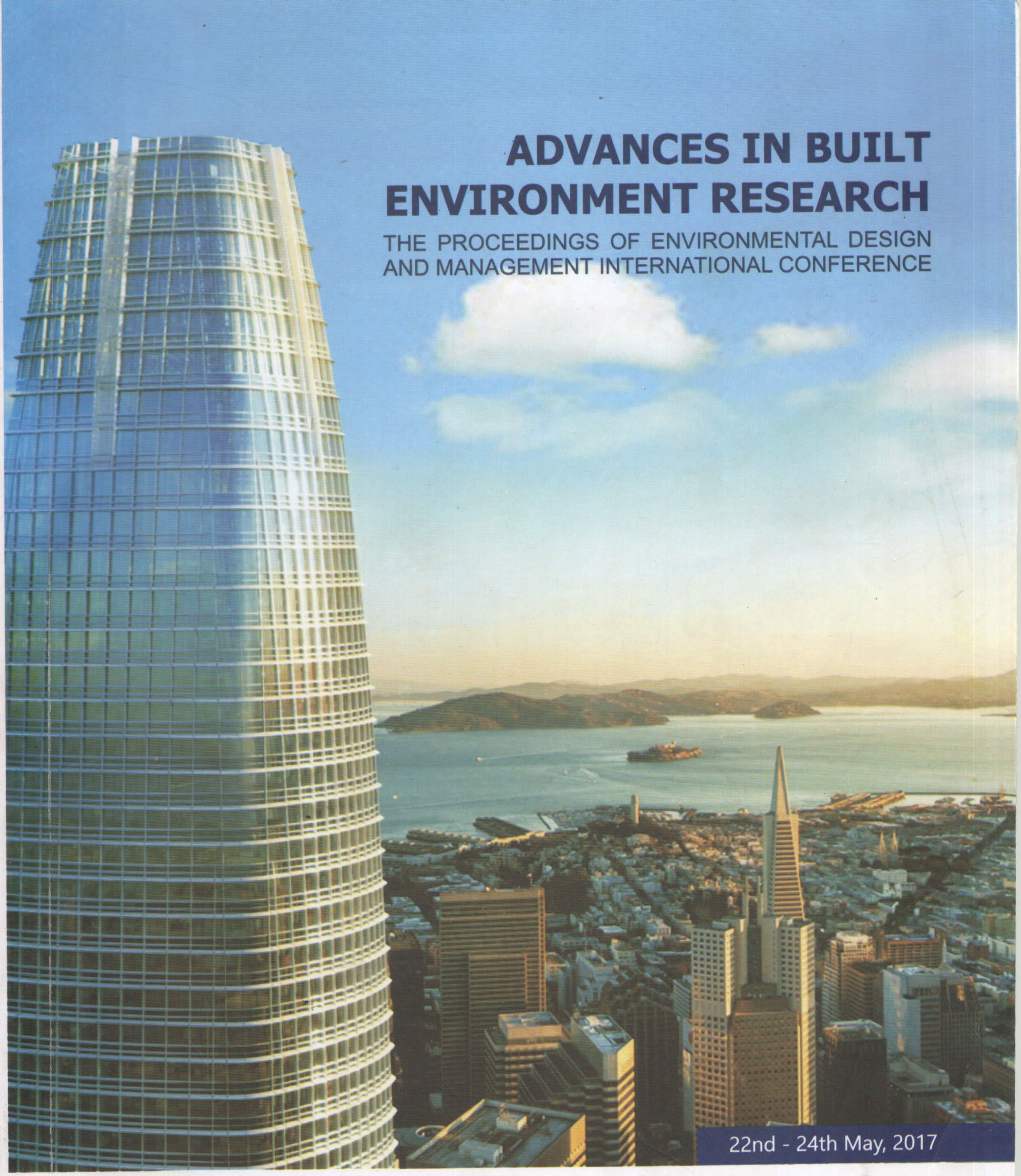

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RISK FACTORS IMPACTING COST AND TIME PERFORMANCE OF MECHANICAL AND ELECTRICAL SERVICES PROJECTS

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ABSTRACT

Mechanical and electrical (M&E) services project is complex in nature and involves a large number of specialist organisations entering the project life cycle at different stages with different lines of relationships, responsibilities and risk management capabilities. Hence, a number of risk arises at the design and installation stages which results into poor cost and time performance in M&E services projects. This paper identified and rank the risk factors affecting cost and time performance of M&E services project. A total of 30 risk factors identified from preliminary investigations was adopted as basis for a questionnaire survey to industry practitioners in Nigeria. Mean response analysis was used to determined the probability and severity of the risk factors and risk impact scores was used to rank the relative importance of the risk factors. Analysis of variance (ANOVA) was used to investigate differences of opinions between respondents'. The study identified 23 risk factors (risk impact >3.5) impacting M&E service projects. Out of these risk factors, 7 has significant impact while the rest have moderate impact. The 7 risk factors in order of their significance are: high foreign materials content, poorly prepared tender document, late involvement of M&E engineers, non-involvement of specialist designers, government policy change, poor specification and poor coodination of design imputs. In addition, ANOVA results show that no significant difference exists among the professionals on these 7 risk factors. This suggests that the risk level of M&E services project is high. The identification and ranking of the risk factors has practical implication in M&E services project. The risk identification and ranking table is a good tool for assessment of risks related to M&E services at project inception. This will allow the client and contractor to understand the high risk areas in M&E services project and, where applicable, assign responsibility for those risks to the party or parties best situated to control them.

Keywords: cost and time performance, mechanical and electrical services; Nigeria; practitioners; risk.

INTRODUCTION

M&E is considered to be one of the riskiest aspect of a building project for several reasons. Firstly the value and complexity of M&E project in modern buildings is increasing and a typical M&Eservices cost could represent between 35-70% of the total cost of a building (Aibinu, Dassanayake, Chan, and Thangaraj, 2015). As buildings grow in size and complexity, M&E also tend to be more sophisticated and difficult to manage from design to installations. Consequently, a huge cost overruns and significant delays resulting from frequent design changes (Mok, Tummala, and Leung, 1997; Lam, 2006). Secondly, M&Eservices is complex and dependent upon the completion of other critical elements of buildings such as building fabrics and finishes (Barton, 1983; Gura, 1984 ;Churcher, 2009).Thirdly, the complexity of M&E services projects requires division of roles and responsibilities among the client, design team, specialist designer, contractors and specialist subcontractors (Lam, Gibb, & Sher, 1997; Lam, 2006). These project participants enter the M&E project life cycle at different stages with different roles,responsibilities, risk management capabilities, and risk bearing capacities with conflicting interest. Therefore, leading to significant interface risk among the project team that materialized throughout the lifecycle of the project (Hanna, Bodai, & El Asmar, 2013). Lastly, in developing countries such as Nigeria, M&E services project is characterized by high foreign materials content (Akinpelu, 2009), making equipment cost susceptible to import duties and change in exchange rate, exposing clients to limited choice of specified equipment which may be obsolete at the time of delivery as well as unpredictablelead time.

More importantly, project participants often fail to see that risk generated in one stage of the project can have a significant knock-on impact throughout its later stage. In particular, poor risk assessment and risk allocation through contract, late involvement of project participants in the design phase could lead to higher materialized risk (Smith, Merna, & Joblin, 2006). Poorly designed project delivery approach can lead to delays, higher costs, and ultimately unhappy clients (Boussabaine & Kirkham, 2003; Babalola, 2012). This paper reports findings on risk factors affecting cost and time performance of M&E services projects in Nigeria. The study aims to: identify and evaluate risk factors in M&E services projects; assess the relative importance of the risk factors affecting cost and time performance of M&E services projects. Since project objectives are subject to risk and uncertainties, it is therefore important that the potential risks to the project are identified, assessed and allocated to parties in a manner, which is likely to optimise project performance (Smith*et al.* 2006).Effective risk management provides opportunity to control the occurrence and impact of risk factors that could lead to variations and provides clients with better information upon which to make value for money decisions(Ashworth, Hogg, & Higgs, 2013). Good risk management in the construction industry requires more than purely common sense and instinct (Ashworth *et al.* 2013). If risk is not properly managed, it becomes a threat to project objectives and consequently detrimental to cost, time and quality (Mok, Tummala, & Leung, 1997; Boussabaine & Kirkham, 2003; Smith*et al.* 2006).

CONSTRUCTION PROJECT PERFORMANCE AND RISK

Project performance are derived from project objectives which are derived from the objectives and success measures of the organisational level (Vandevelde, Dierdonck, &Debackere 2002).
Fundamentally, clients (organisational) project objectives focus on three factors critical to project success namely quality, time and cost (Walker 2007). Time is described as the time from the present until the completion of the project, the point when the project ends and is absorbed back into the core client business (Winch, 2010). According to Walker (2007) time can be assessed on a continuum from time is "of the essence" to time is "at large", of the essence means that where the project is to be delivered one day late then it would be of no value. While cost includes all costs associated with the capital costs of the project, measured on a continuum between the budgets we have is tight to we have flexibility in budgeting (Kelly and Male 2002). Quality is subdivided into technical, functional and aesthetic aspects of the project. However, Project cost and time performance are the most common measures in the project management literature (Walker, 2007). Risk is generally considered as the impact of the uncertainty on the achievement of project objectives (Jaafari, 2006; Winch, 2010). Risk is defined as uncertainty of outcome, whether positive opportunity or negative impact. It is an exposure to loss/gain or the probability of occurrence of loss/gain multiply by its respective magnitude (Smith*et al.* 2006). Events are said to be certain if the probability of their occurrence is 100% or totally uncertain if the probability of occurrence is 0% (Jaafari, 2006).

MECHANICAL AND ELECTRICAL SERVICESPROJECTDELIVERY AND RISK FACTORS

M&E services installations are crucial to the smooth running of construction project (Aibinu, *et al.* 2015). According to (Hall & Greeno, 2009)M&E services are specialist work, discrete and complex in nature. The complex nature of this important element of buildings was further outlined by Akinpelu (2009) interms of its design, technical capability, excessive reliance on foreign materials, long gestation period for project completion, initial capital involved, contract documentation and administration. However, the complexity of M&E services are too often ignore at the inception of a building projects. For instance, building process is generally divided into a design function, a construction function, and a coordinating function (Churcher, 2009). Within the design team, the design coordination function is usually coordinated by the Architect while the construction function is coordinated by the main contractor (Lam *et al.* 1997). Perhaps, the Architects thinks in terms of aesthetics, the structural engineers think in terms of loads and stresses, the QS in terms of costs, the services engineer in terms of internal environmental consideration and the services subcontractors in terms of production methods (Barton, 1983; Gura, 1984). This practice follows that, the Architect and the structural engineer produce pictorial and dimensional drawings in the form of plans, sections and elevations. The services engineers communicate by means of diagrammatic presentations since working drawings are not part of his normal services(Lam *et al.* 1997).

Consequently, most M&E services in buildings often failed to meet clients' requirements because of faults in pre-design and design phase; defects in installation stages and malfunction during testing and commissioning (Heimonen, Immonen, Kauppinen, Nyman, &Junnonen, 2000).Gura (1984), maintained that the traditional method of sequential design development delays project completion because contractors' areas of specialisation are not taking into consideration during design. Gura (1984), explained that M&E engineer required specialist advice at this stage of design development, but specialist designers are not usually involved because of the sequential way of design development. Pavitt and Gibb (2003) considered that non-involvement of specialist contractors always bring about serious problems during construction, especially at the interface between the M&E design team and contractors. Marsh (2005) observed that this normally occur because of the following reasons:

- Communication gap between designers is often caused by poor coordination of the various design inputs.
- lack of management at interfaces and blurred divisions of responsibility"
- Procurement of specialist contractors' design – (specialist contractors are not contractually recognised as a member of the team).

The resulting problems were identified as design related problems and coordination problems.

Design Related Problems

According to Mathews and Howell (2005), M&E services and other related trades were generally brought into the design process by the main contractor at tender stage. Then the specialist services contractors receive information from the main contractor, process client requirements at their individual organisation level without input from the client and even designers (Marsh, 2003). M&E design activities may be undertaken by different types of organization, such as consultants who only do the systems design; manufacturers who design and manufacture; and installers who design and install (Churcher, 2009). In essence, the final design comes from a specialist designers/ contractors/manufacturers and they are not usually involved in the design development. In most cases good ideas are held back by specialist contractors in order to gain a competitive advantage during the tender Buys and Mathew, (2005) and this makes it difficult for design consultants to optimise design solutions(Churcher, 2009).Rawlinson and Dedman (2010) stated that most M&E works involve an element of design by specialist designers that are not involved early on the project. These specialist design engineers (i.e. HVAC, IT, Security and Communications, Plumbing, and Fire Fighting) have based their art on different backgrounds, training and development, leading to lack of appreciation of each other's problems (Michie, 1981). Moreso, in most cases these specialist engineers are not usually reflected in the conditions of engagement, forms of contract and actual management of M&E projects (Pavitt and Gibb 2003).

Coordination Problems

Baldwin and Chan (1994) outlined the probable areas of conflict resulting from lack of coordination as follows: services conflicting with the structural frame; discrepancies in dimensioning as stated on different drawings; improper reservation of holes; conflicts between two or more services; differences between the dimensions of the actual equipment and those in the detailed design; differences in the location of equipment; improper arrangement for the sequence of works; difficulties in the identification of access points and services; difficulties in the support and fixing of services; insufficient space for the completion of adjacent finishing works and difficulty in inspection, commissioning and maintenance.

According to Marsh (2003), none of the standard forms of contract fully respect the complex interrelationship required for a successful installation of M&E services project in buildings, and the major drawbacks of these standard forms of contract when dealing with services include: lack of interconnectivity between the various contracted parties; lack of defined design responsibility; lack of provision for commissioning and/or testing; lack of provision for contractor's design portion; lack of provision for detailed costing other than capital cost; lack of provision for maintenance or system operation. Marsh (2003) further explained that, this lack of standardisation, together with the dominance of imposed conditions set by the main contractor creates a chain of liability that does not allow a direct contractual relationship between client and subcontractor.

Design related problems and coordination problems are considered as risk because the smaller the level of information available at the early design stage of a construction project, the higher is the level of risks and uncertainties (Odeyinka, Weatherup, Cunningham, Mckane, & Larkin, 2010). For instance, the risk allowance at project inception stage can be significant percentage of the total estimated cost, whereas after completion, the requirements for risk allowance will be zero (RICS, 2012). Therefore, inadequate design information are considered as potential risks source that could negate the achievement of M&E services project objectives.The complex nature of M&E services makes risksinevitable in the design of M&E and the amount of risk that is considered acceptable is the challenging job that designer faces (Mok*et al.* 1997).According to Lam*et al.*(997) all M&E projects have risk associated with them and one of the major difficulties for the designer is to manage and eliminate that risk.Riskmanagement is about quantifying the outcome of alternative decisions, ensuring the decisions being made today will provide a satisfactory basis for decisions tomorrow Marsh (2003).

RESEARCH METHODS

The main objectives of this study was to identify risk factors affecting cost and time performance of a M&E services projects. Based on the literature review (Barton, 1983; Gura, 1984; Lam, Gibb, & Sher, 1997; Churcher, 2009), a preliminary list of factors was prepared in order to explore and evaluate the risk factors influencing cost and time performance of M&E services project. The initial risk factors identified was further reviewed and verified by 4 industry practitioners, these practitioners have been involved in the design and installation of M&E services project. The practitioners were asked if they consider the risk factors identified as contributing to poor cost and time performance of M&E services project. Data were obtained using a structured questionnaire on 30 risk factors identified from preliminary investigations. The questionnaire was based on a 7 point Likert Scale grade ranging from 1= "extremely low", 2 = "very low", 3 = "low", 4 = "moderate", 5 = "high", 6 = "very high", 7 = "extremely high".

Lam (2006) considered that a simple approach to risk management is to perform risk analysis at project inception by developing a table showing the type of risk to M&E project, its possible causes, its potential consequences (low,L, medium, M, and high H); the severity/impact of the risk (L, M, H) and finally what would be the typical safeguards. Boussabaine and Kirkham, (2003) called this a risk matrix, whereby for each of the identified risks, a score is assigned for the probability and severity facets of each risk . Boussabaine and Kirkham (2003) said that there are two dimensions to a risk matrix, it looks at how severe and likely an unwanted event is and that the combination of probability and severity will give any event a place on a risk matrix. Based on the 7 points Likert scale, data were obtained on both the probability of occurrence and severity of the risk factors.

Respondents to the survey were professionals selected from the register of public and private clients' organisations in the North Central Geopolitical Zone of Nigeria and the population of the study consists of Archtiects, Structural and Services Engineers, Quantity Surveyors and Builders. The respondents were selected based on the size of M&E services components contained in the projects they had executed for the clients in the previous years. This is to ensure that, participants had previously undertaken building projects that have complex M&E services components (i.e. central airconditioning, lift, excalators, fire prevention and fighting installations). The selected participants constitute the sample frame for this study. A total of 145 professionals were contacted via email to seek their participation in the online survey. Only 78 replied our email request showing interest to participate out of which 53 completed the survey questionaire. The SPSS version 20 was used for the statistical analysis. Mean response analysis was performed to rank the relative importance of the risk factors, while analysis of variance (ANOVA) was used to investigate differences of opinions between respondents' groupings.

Characteristics of Respondents

About 43% are Quantity Surveyors, 34 % Engineers, 11.3% are Architects and other professions respectively. In terms of education, 37.7% have Masters' degree, 28.3% Bachelors' Degree, 16.6% HND, 11.3% PhD and 6% other qualifications. Majority (77.4%) are Associate members, while 12.5% are Fellows and 10.1% other professional qualifications. Majority (94.4%) of the respondents are from consulting (49.1%) and contracting (45.3%) firms while very few (5.7%) are from the academia. About 49.1% of respondents have spent between 16-20 years in practice, while 39.6% have spent between 11-15 years and the rest (11.3%) more than 20 years.

DATA ANALYSIS AND RESULTS

The arithmetic mean response analysis was used to establish the relative significance of the risk factors relating to their probability and severity. The approach is used because it represent the central tendency and is widely used in construction management studies (Ameyaw & Chan, 2015). The summary of the probability and severity of the risk factors as perceived by the industry practitioners in the construction industry is presented in Table 1. The impact of the risk factors can be derived by taking the squareroot of the product of probability and severity $(risk\ impact = \sqrt{probability\ X\ severity},$ (Ameyaw & Chan, 2015).This approach to measurement of risk impact is well-established in decision theory domain (Odeyinka, Larkin, Weatherrup, & Bogle, 2012; Ameyaw & Chan, 2015).

The ranking of the risk factors were then based on the respective impact value. As illustrated in Table 1, the mean probability values for the 30 risk factors ranged between 3.05 ('low') and 5.75 ('very high'), the severity scores ranged from 2.47 ('very low') to 5.45 ('high') and the mean impact values ranged between 2.94 ('low') and 5.56 (very high). What this suggests is that overall risks ranged from 'low' to 'very high'. Looking further into the trend it can be observed that 7 risk factors (HR_1- HR_7), based on the magnitude of their impact are considered by the respondents as having high impact on M&E services projects.These identified risk factors are: (i) high foreign material content (ii) poorly prepared tender document (iii) late involvement of M&E services engineers (iv) non-involvement of specialist designers (v) Government policy change (vi) poor specification and (vii) poor coordination of design inputs. These 7 risk factors have risk impact scores >5.

On the other hand, results revealed that 16 risk factors (MR_1 –MR_116) are perceived by respondents as medium risk with risk impact value >3.5. Based on their risk impact scores, 7 risks factors (LR_1 – LR_7) were identified as having low impact on M&E services project. The 3 risk factors with lowest impact score on M&E services are: (i) separation of design from construction and maintenance (ii) difficulties in the identification of access points and services (iii) improper researvation of holes. What this suggests in essence is that respondents don't perceive these risk factors as a major risk factor in the industry. Some of the major risks factors (those with high impact on M&E services project) identified in the study are high foreign material content and poorly prepared tender document. This is the bane of construction industry in Nigeria over the years. Majority of the M&E services components in buildings are imported, hence the local environmental factors are not taken into consideration by manufactures or producers of some of these products.

Table 1: Results of the Questionaire Survey

Code	Risk Factor	Risk probability	Risk Severity	Risk impact	Rank
HR_1	High foreign materials content	5.67	5.45	5.56	1
HR_2	Poorly prepared tender document	5.54	5.37	5.46	2
HR_3	Late involvement of M&E services engineers.	5.49	5.30	5.39	3
HR_4	Non-involvement of specialist designers	5.49	5.26	5.37	4
HR_5	Government policy change	5.30	5.26	5.28	5
HR_6	Poor specification	5.75	4.79	5.25	6
HR_7	Poor coordination of design inputs	5.29	4.97	5.12	7
MR_1	Incomplete consideration of clients'	4.56	4.91	4.68	8

Code	Risk Factor	Risk probability	Risk Severity	Risk impact	Rank
HR_1	High foreign materials content	5.67	5.45	5.56	1
HR_2	Poorly prepared tender document	5.54	5.37	5.46	2
HR_3	Late involvement of M&E services engineers.	5.49	5.30	5.39	3
HR_4	Non-involvement of specialist designers	5.49	5.26	5.37	4
HR_5	Government policy change	5.30	5.26	5.28	5
HR_6	Poor specification	5.75	4.79	5.25	6
HR_7	Poor coordination of design inputs requirements	5.29	4.97	5.12	7
MR_2	Services conflicting with the structural frame	4.58	4.64	4.61	9
MR_3	Lack of effective communication and co-ordination between the key parties.	4.64	4.47	4.55	10
MR_4	Lack of contractual recognition for specialist designers	4.35	4.35	4.35	11
MR_5	Difficulty in managing many specialist contractors by the main contractors	4.50	4.11	4.30	12
MR_6	Inappropriate procurement path for Mechanical and Electrical.	4.09	4.50	4.29	13
MR_7	The need to maintain competitive advantage by specialist	4.13	4.24	4.18	14
MR_8	Clients' reluctance to pay for the services of specialist	4.13	4.15	4.14	15
MR_9	Desire to comply with emerging technologies	4.24	3.86	4.05	16
MR_10	Inexperience Specialist contractors	4.30	3.69	3.98	17
MR_11	Differences in the location of equipment as designed & as installed	3.77	4.01	3.89	18
MR_12	Fast-tracking pressures on design and construction	4.05	3.66	3.85	19
MR_13	Need for energy efficient M&E services components	4.18	3.50	3.83	20
MR_14	Increasing client sophistication	3.75	3.81	3.78	21
MR_15	Blurred division of responsibility	3.56	3.90	3.73	22
MR_16	High cost of co-ordination.	3.84	3.24	3.53	23
LR_1	Compliance with Statutory requirements.	3.52	3.45	3.49	24
LR_2	Improper arrangement for the sequence of works	3.18	3.81	3.48	25
LR_3	Discrepancies in dimensioning as stated on different drawings	3.33	3.50	3.42	26
LR_4	Difficulty in inspection, commissioning and maintenance.	3.22	3.11	3.16	27
LR_5	Separation of design from construction and maintenance.	3.16	3.03	3.10	28
LR_6	Difficulties in the identification of access points and services	3.05	2.90	2.98	29
LR_7	Improper reservation of holes	3.50	2.47	2.94	30

High Risk =HR; Moderate Risk (MR); Low Risk (LR)

The ANOVA results (Table 2) show that no significance difference exist in the mean score among the respondents on each of the 7 risk factors identified as having high probability of occurrence (HR_1 F= 1.646, p>0.05, HR_2 F= 1.023, p>0.05, HR-3 F= 1.445,p>0.05, HR_4 F=2.128, p>0.05, HR_5 F =.584, p>0.05, HR_6 F= 2.883, p>0.05, and HR_7 F = 1.174,p>0.05). The results, in essence show that the respondents are unanimous in their scoring of these risk factors. However, for those risk factors that respondents perceived as having medium chances of occurrence, their ANOVA results reveal that no statistical significant differences was recorded except for MR_10 (F=11.769, p<0.05), MR_11 (F = 4.434, p<0.05), MR_13 (F=3.922), MR 14 (F = 17.592, p<0.05) and MR_16 (F= 12.667, p< 0.05). What this suggests is that respondents varied in their perception on the need to maintain competitive advantage by specialist, inappropriate procurement path for M&E

services project, need for energy efficient M&E services components, increasing client sophistication and high cost of coordination as risk factors in M&E services project. For those risk factors perceived as having low probability of occurrence, ANOVA results show that respondents unanimously agreed in their scoring (i.e. no statistical significance difference exist for each of the factors). except for LR_1 (F= 3.922, $p<0.05$) , LR_2 (F=17.592, $p<0.05$), and LR_4 (F=12.667, $p<0.05$).

Table 2: Probability of Occurence

Code	Risk Factor	Risk probability	F-Stat	P-Value
HR_1	High foreign materials content	5.67	1.646	.533
HR_2	Poorly prepared tender document	5.54	1.023	.367
HR_3	Late involvement of M&E services engineers.	5.49	1.445	.245
HR_4	Non-involvement of specialist designers	5.49	2.128	.149
HR_5	Government policy change	5.30	.584	.562
HR_6	Poor specification	5.75	2.883	.065
HR_7	Poor coordination of design inputs	5.29	1.174	.421
MR_1	Incomplete consideration of clients' requirements	4.56	1.322	.341
MR_2	Services conflicting with the structural frame	4.58	2.214	.159
MR_3	Lack of effective communication and co-ordination between the key parties.	4.64	1.647	.234
MR_4	Lack of contractual recognition for specialist designers	4.35	3.809	.059
MR_5	Difficulty in managing many specialist contractors by the main contractors	4.50	.789	.460
MR_6	Inappropriate procurement path for Mechanical and Electrical.	4.09	3.032	.057
MR_7	The need to maintain competitive advantage by specialist	4.13	.481	.634
MR_8	Clients' reluctance to pay for the services of specialist	4.13	.975	.454
MR_9	Desire to comply with emerging technologies	4.24	1.096	.342
MR_10	Inexperience Specialist contractors	4.30	11.769	.000**
MR_11	Differences in the location of equipment as designed & as installed	3.77	4.434	.017**
MR_12	Fast-tracking pressures on design and construction	4.05	2.488	.093
MR_13	Need for energy efficient M&E services components	4.18	3.922	.026**
MR_14	Increasing client sophistication	3.75	17.592	.000**
MR_15	Blurred division of responsibility	3.56	2.564	.087
MR_16	High cost of co-ordination.	3.84	12.667	.000**
LR_1	Compliance with Statutory requirements.	3.52	2.413	.061
LR_2	Improper arrangement for the sequence of works	3.18	1.753	.184
LR_3	Discrepancies in dimensioning as stated on different drawings	3.33	1.367	.435
LR_4	Difficulty in inspection, commissioning and maintenance.	3.22	1.513	.398
LR_5	Separation of design from construction and maintenance.	3.16	2.570	.091
LR_6	Difficulties in the identification of access points and services	3.05	1.046	.192
LR_7	Improper reservation of holes	3.50	2.113	.097

CONCLUSION

A typical M&E services project is complex and have many participants, those who carry some share of the risks. Some risks are carried by the construction contractor, some by clients or the design team. This study has identified and rank risk factors impacting cost and time performance of M&E services project. A total of 30 risk factors identified from previous studies provide basis for questionaire design administerd to industry practitioners. Mean response analysis of the probability and severity was used in determining the scores of risk factors, and the risk impact score used to rank the significance of the factors. In general, it can be concluded that 7 risk factors were identified as having high imapct on M& E services project. They include:high foreign materials content, poorly prepared tender documemt, late involvment of M&E engineers,non-involvement of specialist designers, government policy change, poor specification and poor coodination of design imputs. Analysis of variance revealed that no significant difference exist in the mean score among the the respondents on each of the 7 risk factors identified as having high impact. This calls for concern among the stakeholders in building and construction indusrty in the country.

The identification and ranking of the risk factors has practical implication in M&E services project. The risk identification table is a good tool for assessment of risks related to M&E services at project inception. As significant component of successful risk management begins with how well the project participants allocate risks at the contract formation stage. This will allow the client and contractor to understand the high risk areas in M&E services project and, where applicable, assign responsibility for those risks to the party or parties best situated to control them. In addition, this could be use as part of invitation to tender for M&E services projects where each tenderer will be required to indicate how they intend to solve the problems during the construction phase of a building project. This will enable the various parties to M&E services project to evaluate their capacity to manage these risks at the outset of the project.

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