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ASSESSMENT OF IMPACT OF BUILDABILITY AND MAINTAINABILITYANALYSIS ONBUILDING DELIVERY IN NIGERIA

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ABSTRACT

The process of delivering a project to the owner/client on time, within cost and specified quality standard requires the collaborative efforts of different professionals. More often than not, builders are not involved in the design stage to review the production information produced by these professionals. This does result in designs that are not construction friendly or cost prohibitive in terms of maintenance. Thus, this work is carried out to assess the impact of buildability and maintainability analysis on project delivery. A survey of expert opinion on the impact of buildability and maintainability was conducted. Structured questionnaire was designed and administered to senior high ranking construction professionals in two companies undertaking different building projects; and Relative Importance Index (RII) was used to analyze the collected data. Both projects recorded RII≥0.80 for buildability analysis in "facilitating ease of construction" and "reducing design error". Both projects also recorded high relevance of RII ≥0.900 for maintainability analysis in reducing maintenance cost, guaranteeing end user satisfaction and increasing the lifespan of the project. From the result of our findings, it is concluded that buildability and maintainability analyses have significant impact on project delivery. The thrust of buildability is at the design stage so as to affect ease in the construction phase; while the thrust of maintainability is at the operation/use phase of the building. Thus, buildability and maintainability assures best performance throughout the life cycle of a building or component. It is therefore recommended that builders should be involved in the design stage so that they can make professional contributions to production information, as this will enhance successful delivery of building projects and satisfaction during operation/use phase.

Keywords: *Buildability; Maintainability; Building Delivery in Nigeria*

INTRODUCTION

Background of the Study

The process of delivering a project to the owner/client on time, within cost and specified quality standard requires the collaborative efforts of different professionals in the construction industry; such as: Architects, Builders, Engineers, Quantity Surveyors, Town Planers and Estate Surveyors. These various professionals or consultants more especially Architects, Quantity Surveyors and Engineers produce the production information which requires the professional input/contribution of a builder before work commence on site (Bamisile, 2004). One of the essential professional input/core services of a builder during project execution (design stage) is buildability and maintainability analysis. According to Bamisile (2004), buildability and maintainability analysis is the first step/stage at which professional builder can make contribution at the design stage, through studying the production information (ie drawing, specification and schedules). In addition, Bamisile maintained that buildability involves a comprehensive study of the production information to take note of interfacing details, such as discrepancies, Omissions, errors, over/under design. In this process, a builder is to study the production information from production and maintenance points of view and recommend ways in which the design could be more construction/ production friendly to ensure that the client derive value for his money and sustainability of the image of construction industry at large. Similarly, Ogunbiyi (2015) highlighted that, buildability and maintainability comprises the study of the production documents meant for a building project and produced by other consultants on the project such as working drawings, Bills of Quantities and specification. The purpose is to access if the building on paper can stand in reality with a minimal, no error in construction. Obiegbu (2009) reported that, buildability and maintainability helps to identify the most cost effective methods of site execution (production), future maintenance and to draw the attention of designers to any part of the design, working drawings, schedules and specification that could be an impediment in achieving the client's objective. In the same vein, Obiegbu maintained that, buildability and maintainability analysis which is one of the roles of the professional builder aims to achieve value for the client cost optimization, time optimization and getting it right at first and only attempt.

According to Nawi, et al (2009) and Trigunarsyar (2004), the concept of buildability and maintainability evolved in the late 1970's for integrating design/engineering, construction operating knowledge for the purpose of increasing cost efficiency, quality of projects and optimum project objectives in the construction industry. In the same vein, Nawi maintained that, nations and some construction industries that embraced this concept have either infused them into their procurement processes or evolve novel procurement options reflecting and delivering benefits of the new knowledge. For example, within two decades of its evolution, buildability/constructability concepts have been highly developed and applied in countries like USA, UK and Australia. In addition, studies have demonstrated/proved that improved buildability/constructability has resulted in significant savings in both cost and time required for completing construction projects in the above mentioned countries (Russel et al., 1992, Jergeas and Vender put, 2001). Moreover, construction industry in U.S.A was reported to have improved and gradually showing preference for integrated project delivery options as championed by constructability concepts. There were also surveyed indicators that the U.S.A construction industry was responding to the benefits of integration (Arditi, 2002). In addition, Eng (2002) reported that, buildability or maintainability has been used and evolved in the construction management in the late 1970's in united kingdom, but its potential was not been fully exploited in construction industry at that time. Nowadays, buildability is increasingly becoming an integral part of the construction industry in many countries because it was a technique used to manage the construction process during the preconstruction stage.

According to Chew (2010), "Maintainability is the capability to attain the best performance throughout the life cycle of a building or component at the minimum life cycle cost." Maintainability if neglected at the design and construction stages will result in buildings that are difficult or costly to maintain. In addition, Frank (2013) highlighted that, maintainability in building design is achieved when the design is conscious of the ease, safety and cost of maintenance, whilst not compromising building standards and quality. Therefore to achieve maintainability, Seeley (1987) stated that designers ought to find answers to how building elements and components can be reached for maintenance works, how it can be cleaned, what is its lifespan and how it can be changed when it out lives its usefulness. However, Shohet and Lavy (2006), identified in their study: four key Performance Indicators (KPIs) that affect maintenance management of health facilities in Isreal. These include: Assest Development, Organisation Management, Performance Management and Maintenance management. In addition, to these four KPI'S the authors propose an additional two Key Performance Indicators (KPI'S) namely users factors which include user expectations, usage of the facilities, inability to report faults in a time timely manner and vandalism by users. The second KPI that has been introduced is organization factor based on the need for strategic maintenance management that will see maintenance needs being addressed at strategic and operational levels in line with organization goals.

STATEMENT OF THE PROBLEM

Building projects in Nigeria are incessantly plagued by change orders and reworks. The multiplier effects of these include compromising the integrity of the structure, contractual conflicts, cost escalation, and schedule slippages. It is therefore imperative to examine methodologies that assure sound design, construction and delivery. Buildability and maintainability analysis is mentioned as one such methodology that allows input into the design, so as to positively affect both the construction and also the operation phase of the building. Thus, this work is carried out to assess the impact of buildability and maintainability analysis on project delivery.

DEFINITION OF TERMS

There are various definitions of buildability and maintainability analysis by different scholars in the construction industry. According to Mbamali et al. (2005), Buildability is defined as the extent to which a building design facilitates the ease of construction; in the same, Mbamali maintained that buildability is a

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British term while constructability is an American term which is defined as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost. Bamisile (2004) defined buildability as the ability to construct a building efficiently, economically and to an agreed or specified standard from its constituent materials, components and sub-assemblies. In a similar vein, Fisher and Rajan (1986), defined buildability as a measure of the ease or expediency with which a facility can be constructed. Again, buildability is often described as integrating construction knowledge, resources, technology and experience into the engineering and design of a project. A widely accepted definition of buildability is that of the Construction Industry Research and Information Association (CIRIA, 1983), stated that buildability is the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building. According to CII (1987), buildability/constructability can be defined as the optimum use of construction knowledge and experience in the planning, procurement and field operations to achieve overall project objectives. It is obvious from the definition that the application of constructability principles during the project life cycle is very important in order to reduce or prevent error, delays, disputes and cost overruns. To enhance buildability therefore, the most suitable project procurement methods should be adopted. In many developed countries, much research effort has been directed at improving constructability through integrated effort of owners, designers and constructors (Bakti et al. 2003). According to Bamisile (2004), Maintainability is defined as the degree to which ease of maintenance has been designed into a proposed building to optimize access and cost effectiveness during the use of the building. Also, Bamisile went further to state that, maintenance is the work undertaken by professionals in order to keep or restore every part of the structure to an acceptable standard. Therefore, the issue of maintenance should not be an afterthought. It must be taken into consideration at the design stage of the building process.

Comparison between Buildability and Constructability

It is important to note that buildability and constructability are terms that can used interchangeably. Based on comprehensive literature study, the term Constructability, is widely used in U.S.A, while buildability term is often used in UK. According to, Mbamali (2005) buildability is a British term while constructability is an American term which is defined as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost. Wong et al (2007) highlighted, that constructability is concerned with the whole process of project development to facilitate construction efficiency and achieve project goals. By contrast buildability, deals with construction efficiency seen at the design stage, while Constructability covers broader aspect spanning various stages in building development. Both concepts indeed refer to the optimal use of resources for the construction or ease of construction

Historical Background of Buildability and Development of Buildability in Building Construction Industry

The practice of buildability is as old as building construction industry. In the past, the practice of design and construction were conducted by a single master builder who was a skill craft man. The master builder was responsible to produce the design as well as managing and controlling the construction works. As a result of this, the problems related to construction process were taken naturally into the design consideration when the design was formulated (Jergeas, 2001; Zainuddin, 1997). However, as projects become increasingly complex due to emergence of new building materials, construction technology, user demand for high technology of service facilities etc. Various professions emerged to provide the required demands such as design and construction. The establishment of various professionals in the construction industry (such as Architecture, Structural Engineers, Service Engineers, Landscape Architect, Builders and Specialist Contractor etc.) led to the division in the 18 century. Further division in the industry accelerated since then, when greater understanding of engineering principles and other specialized areas were required to fulfill the growing needs of the construction industry. Thus unavoidable needs to provide the distinct roles and responsibilities which design task into several other specialist task such as Civil Engineers, Structural Engineers, Service Engineers and Quantity Surveyors.

In addition, the separation of design and construction in the industry is considered as the practical approach to suite UK requirements and was not challenged until 1962 when (Emmerson's report of 1962)was produced, suggesting that the separation was considered as a major contributory factor to the inefficiency of the UK construction industry. This investigation inspired further awareness of constructability, which was further confirmed in 1964 by (The Banwell Report 1964) where it was suggested that "design and construction must be considered together; and that in the traditional contracting situation, the contractor is too far removed from the design stage at which his specialist knowledge and techniques could be put to valuable uses. That is, the builder is a member of the design team and should be in it from the start". Other different reports like NEDO report of 1975, and a strong new opinion from within the construction industry emerged in the 80's suggesting the need for adoption of constructability concept in the design and construction of buildings. In Nigeria, the concept and content of constructability is not well known. Although some researches has been done in the area, the industry still rely on the traditional

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method of construction with the regard for the benefits derived from adopting buildability/constructability concept in project delivery

LITERATURE

Impact of Buildability and Maintainability in Minimizing/Reducing the Overall Project Cost

Akpan (2010) reported that, the cost of a product including projects is highly influenced by its design. However, the cost information at this stage is always difficult to assess with some certainty. If the projected cost of a product being designed exceeds the cost limit, one of two things must be done, either to discontinue with further developmental effort or to redesign to meet at least most of the specifications as desired. In addition, the most important step of cost estimation is the construction of the cost models that can give meaningful cost estimates based on the collected data. Since a large proportion of the product cost is influenced by product design, it is important to obtain the cost estimates as early and quickly during design phase. In a similar vein, it implies that implementation of buildability analysis at the design stage/preconstruction stage will lead to reduction in the overall project cost. Because buildability is aimed at scrutinizing or assessing the design process to see how it can be more construction friendly. According to Mbamali (2005) stated in his definition of constructability as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost. Low *et al.* (2008) stated that, the aim of buildability is to ensure the impact of design details are recognized and considered in the earlier stage to reduce or prevent errors, delays and allow a cost control to the overall project. In addition to this, it will enhance the productivity and competitiveness of the industry. Also, Francis *et al.* (1999) reported that, better buildability could contribute to early completion of projects and buildable designs would lead to saving in project costs and reduce occurrence of change orders.

Tinidiiwensi (1996) stated that, the integration of good buildability into good overall designs is the responsibility of the design team, research in Uganda and elsewhere in the world has shown that good buildability leads to major cost benefits for clients, designers and builders. According to Amade (2016)highlighted that, construction managers display the benefit of adopting constructability in terms of cost reduction within the range of one to fourteen percent of the total cost. Regardless of the stage of its implementation, constructability centers on the design prior to the improvement of constructability during the planning and design stages, the key to achieving this during construction phase of the project is normally through an effective feedback construction knowledge system.

According to Ipenz (2008), buildability or constructability is a project management technique used in reviewing construction processes from the start to finish stage during the pre-construction phrase. It normally identifies obstacles before a project is actually built to reduce or prevent errors delays and cost overruns. Kamari and Pimplikar (2012) added that, constructability is a project technique for reviewing construction processes from inception to finished stage during the pre-construction phrase. Also, it is usually a means for identifying obstacles before a project is actually constructed to help reduce or prevent incidences of error, delays and cost overrun

Ways Buildability and Maintainability Assist Construction Professionals in Project Scheduling and Specification

Engineering/construction professionals require adequate knowledge and the deployment of the right tools to deal with issues of constructability or buildability to ensure efficient and effective delivery of projects within specified time (schedule), cost and quality standards. Buildability or constructability is a project quality improvement technique that if implemented throughout the project delivery process, would help in mitigating issues of schedule slippages, conflict between design and construction team (Akpan et al. 2014).In same vein, Constructability or buildability implementation enables the design professionals to consider how a constructor will implement the design, which otherwise could lead to scheduling problems, delay, dispute and cost related problem during construction process. According to Chua (2003), the application of constructability in UK, USA and Australia reduced the cost and schedule of most projects. In addition, constructability entails the integration of design and construction which could result into significant savings and better performance. Construction input in design can resolve many design related difficulties during construction. Such as those arising from access restriction and incompatible design and construction schedules. Construction input includes knowledge of local factors and site condition that can influence the choice of construction method and in turn, the design.

Problems and Limitation of Buildability and Maintainability Analysis for Effective Project Delivery

Generally, the performance of the construction industry with regards to cost, time and quality of project delivery has not been impressive. Among the Nigerian construction industry, cases of project delays, abandonment, cost overrun and failures can be attributed to a large extent, to lack of adequate knowledge and non-implementation of buildability/constructability in the project delivery process. Rimer (1976), highlighted that, serious buildability problems could impact a project enormously, cost wise and even become a social problem due to future repairs, inconveniences and other perils, including safety. Rimer, maintained that occurrence of buildability problems in a construction project at the point of implementation is a fertile ground for occurrence of a myriad of negative issues, some of which include delays, rework, errors, time and cost overruns litigations, building collapse and in the extreme case, outright abandonment. According to Aina and Wahab (2011) buildability problems arise from complexity of project, faulty and defective working drawings, resistance of client to buildability programmes, budgetary limitation and non-standardization of the design. In addition, clients are continuously impatient with the poor delivery of project requirements with buildability problems increasing in proportional to the period of time

Li and Taylor (2011) define two kinds of extra work that undiscovered rework (which may be induced by unbuildable design) may cause. One is work that was not in the initial project scope but has to be completed to support those parts of the project that are related to the part being reworked, the other type is the work that was in the initial project scope and was initially installed correctly but needs to be reworked because it is closely related to a separate item being reworked. To further underscore the impact of a design/construction alteration induced by buildability issues, Li and Taylor (2011) considered an example of an engineer who designed a highway project and made error in sizing storm sewer pipes passing under the highway. This error was identified at the design stage. During construction the wrong size pipes were installed underneath the pavement and the pipe sizing error was not discovered until after the placement of the pavement. In order to correct the pipe sizing error, the pavement above the pipe must be demolished (work that was completed correctly but required rework due to rework in adjacent systems) and the excavation must be shored (work that was not required as part of the original project scope). The summary is that in complex projects where activities are closely related to each other, the longer it takes to find a mistake, the more additional work can be created in the process of correcting the mistake and the more total performance can be degraded.

Furthermore, Ojo (2010), reported that, in developing countries like Nigeria, often referred to as an emerging economy, the procurement process for construction projects is still predominantly traditional, with the hall mark of separation of design and construction and almost absolute non-participation of the construction team in the pre-contract stages of project evolvement. Also, in Nigeria, more than 65% of construction projects are still delivered through the traditional procurement mode. However, the non-participation of construction experts at the design pre-contract stage of projects is not only because of pre-dominance of the traditional procurement rout. But it is more because of deep seated adversarial relationship among key participants in the project delivery process. It is more a case of professionals at the pre-contract stage protecting their traditional roles and displaying versatility often shown in their being both the designer and the constructor thus counting other roles/participants as irrelevant in the project chain. Again, the separation of design from construction in the traditional procurement option is indeed a fertile ground of occurrence of buildability problems. In addition, the predominance of this procurement option in Nigeria predisposes ample (Ojo 2010).

METHODOLOGY

A survey of expert opinion on the impact of buildability and maintainability on project delivery was conducted. Structured questionnaire was designed and administered to senior high ranking construction professionals in two companies (TAF Africa Homes and Prime West Ltd) undertaking different building projects. 40 questionnaires were administered to each of the companies; 32 were returned by TAF and 24 were returned by Prime West. The questionnaire was designed to determine the elements of successful project delivery that are delivered by buildability and maintainability analysis

Relative Importance Index (RII) was used to analyze the data obtained.

$\text{RII} = \frac{\bar{X}}{k}$

Where $\bar{X}$ is $= \frac{\sum fX}{\sum f}$; and k is the highest weighting point

DATA PRESENTATION AND ANALYSIS

Table 3.1 below show the elements of successful project delivery which are assessed to determine whether buildability and maintainability analysis can deliver. Table 3.2 and 3.3 are presentation of the extent to which buildability and maintainability analysis (BMA) respectively deliver the assessed success factors. Figure 3.1 and 3.2 examines the impacts of BMA on project delivery as scored by the two companies examined.

Table 3.1: Impacts of Buildability and Maintainability

Legend	Impacts
A1	Reducing conflicts
A2	Reducing design errors (over-design or under-design)
A3	Facilitates ease of construction
A4	Reduces change orders
A5	Reducing reworks
A6	Reduce building cost
A7	Assist in effective project scheduling
A8	Support material sourcing and procurements
A9	End user satisfaction
A10	Reduces maintenance costs
sA11	Increase lifespan of the project

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Table 3.2: Analysis of Data on impact of Buildability Analysis on building delivery

	TAF AFRICAN HOMES GOLF ESTATE PROJECT								PRIME WEST LTD UDENWA ESTATE PROJECT							
	Weighting (x)				∑f		RII	Rank	Weighting (x)				∑f		RII	Rank
	1	2	3	4					1	2	3	4				
A1	7	12	15	8	32	3.38	0.8	6th	1	1	2	20	24	3.71	0.93	3rd
A2	0	0	2	30	32	3.9	0.9	1st	0	0	0	24	24	4.0	1.00	1st
A3	0	2	2	28	32	3.81	0.9	2nd	0	0	0	24	24	4.0	1.00	1st
A4	1	2	8	21	32	3.53	0.8	3rd	1	1	2	20	24	3.71	0.93	3rd
A5	1	2	8	21	32	3.53	0.8	3rd	0	3	7	14	24	3.4	0.86	5th
A6	0	0	18	14	32	3.4	0.8	5th	0	6	7	11	24	3.21	0.80	7th
A7	14	17	1	0	32	1.6	0.4	10th	16	8	0	0	24	1.33	0.33	9th
A8	6	14	8	4	32	2.31	0.5	9th	10	8	4	2	24	1.9	0.48	8th
A9	0	4	18	10	32	3.19	0.8	7th	1	5	4	14	24	3.2	0.82	6th
A1	18	14	0	0	32	1.43	0.3	11th	18	4	2	0	24	0.9	0.23	10th
A11	0	4	18	10	32	3.19	0.8	7th	18	4	2	0	24	0.9	0.23	10th

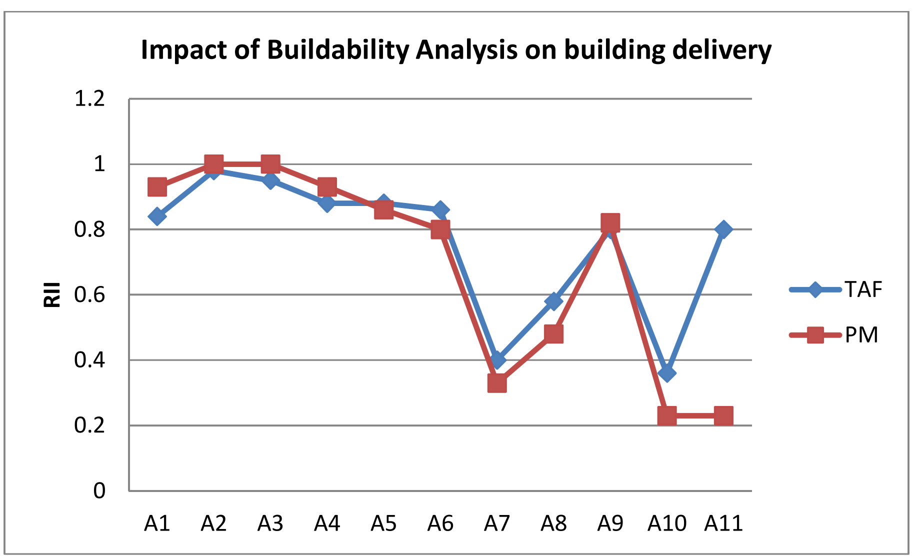

Figure 3.1: Impact of Buildability Analysis on building delivery

Table 3.3: Analysis of Data on impact of Maintainability Analysis on building delivery

	TAF AFRICAN HOMES GOLF ESTATE PROJECT								PRIME WEST LTD UDENWA ESTATE PROJECT							
	Weighting (x)				∑f		RII	Rank	Weighting (x)				∑f		RII	Rank
	1	2	3	4					1	2	3	4				
A1	10	12	8	2	32	2.0	0.5	6th	18	4	2	0	24	0.9	0.23	10th
A2	6	14	8	4	32	2.31	0.5	4th	16	8	0	0	24	1.33	0.33	8th
A3	14	17	1	0	32	1.6	0.4	9th	10	8	4	2	24	1.9	0.48	5th
A4	10	12	8	2	32	2.0	0.5	6th	10	8	4	2	24	1.9	0.48	5th
A5	15	12	5	0	32	1.6	0.4	8th	9	7	7	1	24	2.0	0.50	4th
A6	14	17	1	0	32	1.6	0.4	9th	18	4	2	0	24	0.9	0.23	10th
A7	18	14	0	0	32	1.43	0.3	11th	16	8	0	0	24	1.33	0.33	8th
A8	6	14	8	4	32	2.31	0.5	4th	10	8	4	2	24	1.9	0.48	5th
A9	0	0	2	30	32	3.9	0.9	2nd	0	0	4	20	24	3.83	0.96	2nd
A1	0	0	0	32	32	4.0	1.0	1st	0	0	0	24	24	4.0	1.00	1st
A11	0	2	2	28	32	3.81	0.9	3rd	1	1	2	20	24	3.71	0.93	3rd

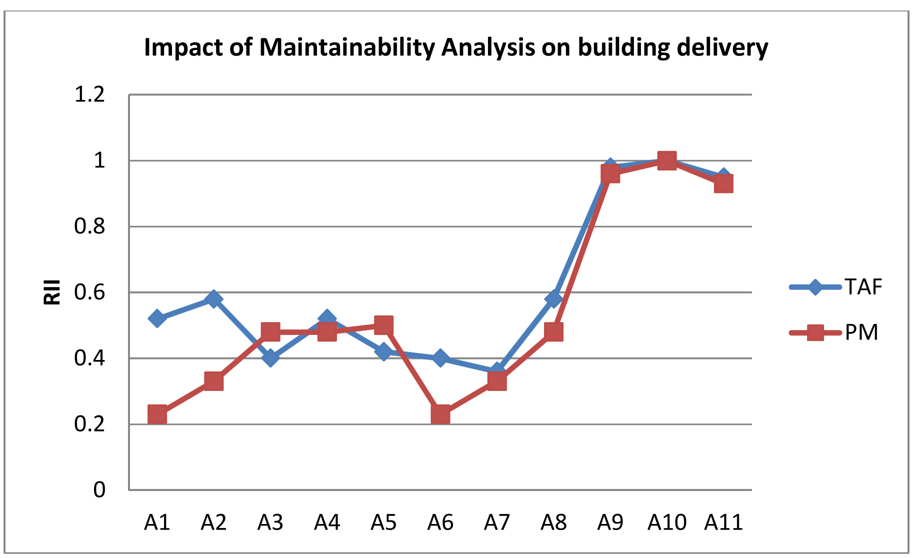

Figure 3.2: Impact of Maintainability Analysis on building delivery

DISCUSSION OF RESULTS

Assessment of Buildability Analysis on Project Delivery

Buildability is seen to significantly improve project delivery (table 3.2). Of the two projects examined, the relevance of buildability is seen in that it delivers benefits to the projects. In the first project, RII ≥ 0.80 in eight of the eleven factors; In the second project, RII ≥ 0.80 in seven of the eleven factors. "Facilitate ease of construction" and "reduce design error" is ranked in first and second place in both projects. This demonstrates that buildability analysis will reduce/minimize design error (overdesign/under design) encountered during the preconstruction phase which will facilitate ease of construction during construction phase "Reduce maintenance cost" is ranked lowest on both projects. This can be explained by the fact that buildability is concerned more on the design and pre-construction inputs to ease the construction phase. However, if appropriate buildability analysis is carried out during the pre-construction phase, and used to affect the construction phase, it will lead to minimization of maintenance during the use/ operation phase of the building.

Assessment of Maintainability Analysis on Project Delivery

It can be seen that maintainability analysis significantly improved project delivery (table 3.3). Both projects examined record high relevance (RII ≥ 0.900) for maintainability in reducing maintenance cost, guarantying end user satisfaction and increasing the lifespan of the project.

CONCLUSION

Buildability and maintainability analysis has significant impact on project delivery. The most significant impact is that it facilities ease of construction and reduce design error (overdesign/under design) usually encountered during construction phase. The thrust of buildability is the design stage so as to affect ease in the construction phase; while the thrust of maintainability is the operation/ use phase of the building. Thus, buildability and maintainability assures best performance throughout the life cycle of a building or component. Buildability and maintainability analysis is the first stage at which a consultant builder can make contribution at the design stage through a comprehensive study of the production information to take note of interfacing details, such as discrepancies, Omissions, errors, over/under design.

RECOMMENDATION

1. Given the significance of buildability and maintainability analysis to project delivery; It is highly recommended that a professional builder be involved at the design stage of a building project to carry out these analyses.

2. There should be a shift from the traditional method of project delivery where there is almost absolute non-participation of the construction team in the pre-contract stages of project evolvement.
3. There should be adequate training and re-training (seminar) for the professionals in the construction industry and the general public on significance of buildability and maintainability
4. Develop tools and procedures for buildability assessment in construction projects

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