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Feasibility Assessment of Tilt-Up Construction in Commercial Buildings

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Abstract: Construction projects are much appreciated by both client and contractor when completed on schedule and within budget so as to avoid cost overruns. The Zambian building sector normally experiences time and cost overruns. This study investigated the feasibility of using tilt-up construction in the construction of commercial building walls. The methodology used consisted of a literature review, a questionnaire survey and a scenario analysis consisting of a hypothetical 4900 square meter commercial building with a height of 8 meters. Sixty-six questionnaires were administered to design professionals operating in the Zambian building sector using simple random sampling and thirty-six were returned giving a response rate of 55%. The data were analyzed using descriptive statistics. Cost analysis was done on a hypothetical building as no contractor was found using tilt-up construction in the construction sector. The study established that tilt-up was, in fact, more expensive than the conventional methods (concrete blocks and in-situ reinforced concrete walls), but it was faster, hence, making it viable in respect to time and not cost in the Zambian construction industry (ZCI). Additionally, necessary expertise was available with the exception of a certified tilt-up practitioner and a sealant sub-contractor in cases where a sealant contractor is needed. The study has identified that currently in the Zambian building sector tilt-up construction can be used when time is more important than the cost. However, challenges such as site size (limited space), the unavailability of building regulation for tilt-up construction and the economic capacity of the client or capacity need to be addressed for enhancing the practical application of tilt-up construction in ZCI.

Keywords: Feasibility, tilt-up, construction, commercial, buildings.

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1. Introduction

Building materials constitute a large percentage of the total building cost of 65%-70% (Ashworth, 2004; Yalley and Kwan, 2008). The choice in material and mode of construction can have an adverse effect on the final building cost and time. Thus, employing the use of materials that are relatively cheaper and long-lasting can aid in achieving lower final building costs. Additionally, the use of construction methods that are fast can help avert costs. With the focus being on commercial buildings, the effect of the choice of materials, and method of construction, becomes more pronounced as the number of materials on commercial buildings is high due to the nature of commercial building projects. This brings about the need for speedy methods of construction. The Latham report (1994) comments on the link between initial and future costs noting that "good design does not necessarily involve high cost, good design will provide value for money in terms of both total costs and costs in use and that the energy and maintenance equations should be uppermost in the minds of the designer and client as well as the appearance of the façade and the effective use of space". The report notes, however, that paying a high price, in itself, does not guarantee quality. While the cost of materials can be constant or costly the cost of construction could be minimized through construction method.

One of the many reasons why building materials are costly in Zambia, can be attributed to the fact that most of them are imported and those that are manufactured locally still have their raw materials imported (Danso, 2013). There is also a high level of use of concrete blocks on commercial buildings as well as residential buildings. These have almost always resulted in a delayed project. This extensive use is attributed to the seemingly low cost of a concrete block and availability of labor. Concrete masonry units (concrete blocks) prove to be time consuming due to its highly labour intensive nature, according to Understanding Building Construction (2017), as well as high cost associated with scaffolding on large commercial structures. Yet these are a common

construction material used using various bonds. Glass and aluminum are also materials used for walling and steel for structural framing in Zambia, however, as earlier mentioned, imported goods tend to have high prices. Reinforced concrete is another material used for wall construction in Zambia, even though it is to a lesser extent as compared to concrete blocks. The method of construction also has an effect on the speed of construction as can be seen with prefabricated construction where components of a building are precast and simply install on site. This can be observed with the use of modern methods of construction (MMC) which are said to result in faster construction. (Kyjakova and Baskova, n.d.).

Clearly in the Zambian construction industry use of brick/block masonry is very common with the uptake of other methods such as precast and panelized construction being slow and seemingly expensive. Nevertheless, it is unclear the measures that have been put in place to cartel the shortfall of time and cost. It has been established that the construction industry in Zambia is marred with cost, time and quality overruns (Muya et al., 2013; Auditor General's Office, 2018). This is more pronounced on medium to large scale buildings. Few studies have been conducted on commercial wall construction more so on tilt-up construction. Therefore, this paper fills this gap in knowledge as it is unclear whether the use of the tilt-up method would be cheaper and quicker compared to existing methods. The following are the research objectives.

A. To determine the nature of commercial wall construction used in the building sector in Zambia.

B. To determine the availability of requirements for tilt-up construction

C. To compare and time and cost of construction for commercial walls using tilt-up construction and other prevalent conventional methods used in the building sector in Zambia.

D. To identify challenges and limitations that may arise when using tilt-up construction in the building sector in Zambia.

2. Literature Review

2.1. Tilt-up Construction

Tilt-up is a method of casting building walls on a horizontal surface, waiting for a sufficient time for concrete to gain strength and then tilting the panel up into its final position using a crane (Tilt-Up Concrete Association, 2011). It is also described, by Construction World Magazine (2013), as "a construction technique where the elements are cast on-site and lifted into their final position, maximizing many of the unique and sustainable benefits of concrete for a cost-effective building technique and efficient construction method". The concrete component is cast on a flat surface, mostly the building slab, to minimize formwork. Tilt-up panels (walls) have the advantage of incorporating openings for doors, windows, services and generic openings alike before the panel can be lifted into place, this allows for time-saving when it comes to forming openings (Tilt-Up Concrete Association, 2011).

This type of construction is used in countries such as the United States, Canada, New Zealand, and Australia successfully as a construction method. The number of tilt-up buildings constructed annually is significantly increasing; one of the factors contributing to this growth is the acceptance of tilt-up as a more creative and construction medium that is cheaper and applicable to nearly all types of markets (Tilt-Up Concrete Association, 2011).

Tilt-up construction provides numerous advantages over steel buildings or traditional construction for warehouses, call centers, retail stores, office buildings, storage facilities and other types of industrial and commercial building construction projects. According to Jay-ton Concrete construction (2016), some of the advantages of using tilt-up include savings in construction cost; timely completion of projects, increased safety; and no need for a factory as panels are cast on-site. However, this construction method is not currently being used in the ZCI, hence, the investigation into the viability of tilt-up construction as it is not known whether this construction method can produce the same results and benefits in Zambia as it has in other countries currently using the method.

2.2. Commercial Building Walls

Various materials can be used for the construction of commercial building walls depending on the nature of the wall to be built. Load bearing and non-load bearing walls are the two broad categories (Chudley and Greeno, 2015). The choice is determined by the use of the building as well as the preferred material by the owner. The following are some of the common materials used in the construction of external walls and their methods of construction.

2.2.1. Concrete blocks

Concrete blocks using mortar in various block bonds are labor-intensive in nature; in addition to the human factor the output per day varies depending on many factors that affect productivity such as weather, motivation, health status, and skill of bricklayer (Understanding Building Construction, 2017). The nature of this type of construction when applied to large commercial structures is costly and time-consuming due to factors such as high cost of labor that will be required as well as scaffolding involved. Safety is another issue to be considered when it comes to the use of concrete blocks in instances where wall height is excessive. However, concrete blocks have proven to be the material of choice when building smaller structures and has been judged to be cost efficient when skilled bricklayers are employed. In addition, a medium structure can be constructed within few weeks at minimum cost. Nevertheless, the use of concrete walling in commercial buildings has been proven to be costly and time consuming.

2.2.2. In-situ reinforced concrete

Similar to concrete blocks, in-situ reinforced concrete walls are time consuming due to the procedure of making formwork for placing. Construction of formwork is time consuming. In addition, it takes time to pour concrete into the form which also needs time to set thereby adding to the overall project time. The large amounts of formwork required also add to the cost of in-situ reinforced concrete walls as each wall will require formwork vertically and on both sides. Aside from the amount of formwork required, the time it takes to make the concrete on site adds to overall completion time of the wall structure of a building unless ready mix concrete is used.

2.2.3. Curtain walls

A curtain wall is a thin frame containing in-fill panels. The main challenge with curtain walls is the high cost of purchase of the materials used such as glass, metal panels or thin stone. Curtain walls are costly due to the material used as well as the fact that they are mostly imported into jurisdictions where there are no factories making the curtain walls. However, curtain walls are quicker and easier to install due to their prefabricated nature.

2.2.4. Steel and other materials

Steel is also used as a construction material for walling. Steel is an excellent material for structural use in smaller buildings under 50,000 square feet (approx. 4,126 meters square). According to DLS Consultancy (2008), steel proves to be cheaper than concrete in the United Kingdom's construction industry, however, conditions prove different in other countries where steel is relatively expensive. In buildings of over 50,000 square feet (4,645m^2), the cost of construction is offset by the cheaper price of concrete. However, an article by Bob Moore Construction INC. (n.d) states that, regardless of which traditional approach is used, steel wall, curtain wall or CMU, building the exterior wall is a time consuming multi stepped process. In Zambia, steel is generally more expensive compared to concrete walling; due to small number of steel manufacturers; same is true for material used in curtain walls such as aluminum and glass. In a study to determine the cost difference between concrete and steel structures, DLS Consultancy (2008) stressed that despite the tremendous increase in prices of ready-mixed concrete and the ban in the importation of sand, "the cost of reinforced concrete structure was lower than that of steel structure." It can be noted that tilt-up is cheaper than block work masonry as well as metal buildings per square meter, taking into account the fact that the United States of America is far more technologically and economically advanced in terms of steel manufacturing than Zambia. Engineering brick wall and precast walls can also be utilized for commercial building construction yet the use of these is not very wide spread in Zambia.

2.3. Construction of Commercial Buildings in Zambia

Another consideration is the cost of construction using the conventional methods such as concrete blocks, in-situ concrete as well as curtain walls. According to the Zambia Development Agency (2016), Table 1 shows average costs of factory-commercial buildings, as this is the type of structure that is mostly being considered in this research.

These are prices for complete construction of factory. Other examples of costs of commercial structures include:

- Mukuba mall in Kitwe, which cost $50 million (K500, 000,000.00) to be built (Afrotourism, 2018).
- Cosmopolitan mall in Lusaka Built for a cost of $26 million (K260, 000,000.00) (Lumba, 2016).
- A two-story building in Lusaka at cost of K1, 000,000.00. (Phiri, 2017).

It can be seen that these costs are quite high which is characteristic of such commercial building projects. High costs can be attributed to the methods used. For instance, in concrete walls, scaffold is required from the time construction of superstructure begins up to the time the project is completed and commissioned which adds to the overall project cost. In a similar way in-situ reinforced concrete walls required large amounts of formwork and a pause at each story for concrete to set, in cases of multi-story commercial structures, which adds to the overall cost of these structures. Finding ways to reduce cost on such large projects would be beneficial to stakeholders in the construction industry. Nevertheless, findings in other construction industries seem to suggest use of various materials do not yield the same results.

Table 1. Cost of constructing factory per meter squared

(Source: Zambia Development Agency, 2016)

Average construction costs of factory building	Cost per meter squared
Factory with reinforced concrete structure	K3,900.00 (US$390.00) to K4,500.00 (US$450.00
Steel portal frame on reinforced concrete	K3,900.00 (US$390.00) to K4,500.00(US$450.00
Factory with clean room facilities	K4,000.00 (US$400.00) to K5,000.00 (US$500.00

In America for instance, Cinemark USA was in the midst of building its 302nd theatre in Mansfield, Texas and everything was on schedule. Cinemark then realized the theatre would not be complete in time for the release of the summer blockbuster movie, thus, the schedule had to change. The originally planned opening was to be July 10. The city of Mansfield wanted it open by July 4. In addition, with the release of the blockbuster movie it was moved up to June 29, a two-week jump in schedule, fortunately the general contractor was using tilt-up construction for this project. As a result, the Mansfield theatre was one of the fastest construction projects Cinemark had ever built, the theatre was actually completed on the 28th and even though the compressed schedule sped up everything, it is still lavish and cutting edge. The project was 42,265 square feet (3,927 square meters).

In South Africa, having noted the success of the tilt-up method internationally, YN construction (2015) evaluated the sustainability and viability of the construction method, YN construction, in association with Tilt-up Technologies Pty (Ltd), built a 6,000 m^2 warehouse under local conditions. It is reported that the success of the project was irrefutable; the project was delivered within budget and with a reduction of 30% in construction time as compared to conventional methods (YN Construction, 2015). Therefore, there was a need to establish the merits of tilt-up in the Zambian building sector. The methodology employed in this study is explained in the next section.

3. Methodology

The study utilised a positivist approach with the main modes of data collection being survey and a scenario analysis. The approach was used to maintain objectivity. Additionally, adhering to what could be measured and observed. A survey was conducted with the target population being consultancy firms (Quantity Surveying, Civil and Architectural), contractors and equipment and plant hire firms as being the major drivers in the utility of construction methods. The target areas were the Copperbelt and Lusaka provinces. The modes of data collection were questionnaire and cost information for the scenario. This was a multiple method approach which was cross-sectional in nature so as to collect the necessary data. The research is original in terms of context as there are few such studies in a developing context (Phillips and Pugh, 2005). The questionnaire was perception (questionnaire)

and requirements assertion (scenario) based so as to have an overview of the perceptions of consultants on the use of tilt-up in the construction of commercial buildings. The selection of respondents was therefore purposive for equipment hire companies and stratified for consultants. The data was analyzed using descriptive statistics such as percentages and frequencies. Additionally, cost analysis (cost of materials, labor, and equipment) and time analysis (time to carryout construction in days and weeks) were conducted. The scenario comprised of a 70 x 70 commercial building with a height of 8 meters. This therefore gave a floor area of about 4,900m^2 and wall area of about 2,249m^2 after deducting for openings.

The data collection was sequential in nature; questionnaire followed by scenario analysis which heavily relied on industry responses. Perceptions on knowledge on tilt-up construction and availability and cost of requirements and challenges and limitations faced were collected using the questionnaire. Further to this time for construction and labor and equipment requirements were also investigated. The later was used to conduct the cost and time analysis in the scenario used.

4. Findings and Discussion

4.1. Characteristics of Respondents

The percentage of respondents for the survey constituted 42% contractors and 58% consultants comprising quantity survey, architecture, concrete specialist contractors and civil engineering background. More than half of the respondents (58.9%) had 1 to 5 years' experience in the construction industry. Those with 6 to 10 years' experience in the industry comprised of 32% of the respondents and those with over 16 years were 2.9%. The respondents were characterized by new entrants in the industry whose views represented those of the firm of origin in terms of practices. The new entrants were also found to be more willing to give information.

4.2. Knowledge on Tilt-up and Preferred Material for Walls

In terms of knowledge and awareness of tilt-up construction, over half of the respondents (58%) were unaware or had no knowledge of tilt-up construction while 42% were either aware or were knowledgeable (Table 2). Therefore, the lack of unawareness and knowledge could be seen to play a big role selection of materials for wall as one cannot select what they are unaware of.

Table 2. The perception on available expertise needed for tilt construction

Expertise	Availability perception
Provision of lifting accessories	97%
Trained crane hire operator	92%
Sub-contractor providing jointing services between steel and concrete	86%
Professional welding services	75%
Placement of reinforcement by steel companies	58%
Sealant sub-contractor	2.8%

For comparison, respondents were asked the preferred building materials of commercial building walls. The respondents revealed that concrete (21) is the most common followed by Reinforced concrete (8) then Precast concrete (3), and steel with walls such as glass, aluminum etc. (4). The least used material was a mixture of blocks and concrete beams (2), mixture of steel and blocks (2) were equally indicated by respondents. Concrete, reinforced concrete seemed to be common materials for commercial building walls.

4.3. Availability of Expertise Needed for Tilt-up

Tilt-up construction needs qualified personnel and relevant equipment for it to be used. The survey established through perceptions the availability of specialists and equipment as shown in Table 2.

Table 2 shows that the skill in short supply was that of sealant contractors though respondents were confident that the number of specialist sealant contractors would increase if the tilt-up methods of construction increased in the industry. These would also be true for placement of reinforcement steel companies as currently contractor firms do not see the need to offer a service that is not currently demanded.

4.4. Comparison of Tilt-up with other Conventional Methods of Construction

A comparison was done for materials commonly used for the construction of commercial building walls as shown in Table 3. In-situ reinforced concrete and concrete blocks as these were indicated as the preferred materials for constructing.

Table 3. Comparisons of tilt-up and conventional methods of construction

	Based of respondents perceptions		Based on scenario	
	Time	Cost	Time	Cost
In-situ reinforced concrete	Slower than Tilt-up but faster than concrete block walls	More expensive than Tilt-up and concrete blocks	(66 days/ 14 weeks)	K939,322.00 (US$939.32)
Concrete blocks	Slower than Tilt-up and in situ reinforced concrete walls	Cheaper than Tilt-up and in-situ concrete walls	(78 days/ 16 weeks)	K918,039.00 (US$918.04)
Tilt-up reinforced concrete	Faster than concrete blocks and in-situ	Cheaper than in-situ walls but more expensive than concrete block walls	(25 days/ 5 weeks)	K1,074,288.00 (US$1,074.29) (8x7m panel): K1,027,493.00 (US$ 1,027.49) (8x3m panel)

The summary of this comparison based on perceptions established in the questionnaire survey and calculations based on the scenario. The feasibility of using tilt-up construction was only beneficial in terms of time as it was perceived to be faster than in-situ reinforced and blockwork wall. However, it was found to be more expensive is only preferred when speed is needed and cost can be ignored.

4.5. Challenges and Limitations associated with Tilt-up Currently in ZCI

Tilt-up construction though found to be fast and cheaper in other countries (YN Construction, 2015) is not without challenges and limitations. The three notable ones in the Zambian building sector include industry knowledge, availability of necessary skills and weather delays as it is best utilized in dry weather.

Most of the respondents indicated industry knowledge (88.9%) as the biggest limitation followed by availability of necessary skills (63.9%) and the weather indicated by 38.9% of the respondents. Those who are unaware of the method (58%) cannot adopt it. From the survey results, the main limitations noted were categories as stemming from building regulations, site location, space and economic capability as follows:

Slightly above half of the number of respondents (52.8%) submitted that lack of buildings regulations specifically addressing tilt-up construction was a hindrance to the use of the method with those who thought that lack of regulation had no bearing on the use of tilt-up (47.2%) being less than half. Therefore, it is not so unclear the role that regulation plays in the use of certain construction methods or standards since even for methods such as use of prefabricated construction where standards have been adopted there seems to be a slow intake as highlighted by one of the respondents.

As whether site location was perceived as one of the likely limitations to the use of tilt-up concrete in Zambia; 54.3% were in agreement, 8.6% were undecided while 37.1% disagreed with the assertion. The reasoning behind this was that for some projects located in tight spaces, or where other structures enclose the site, it could limit the movement of crane on site, hence, rendering the method in capable of being used. Space was not considered to be a limitation to the adoption of tilt-up as there is a lot of space available in Zambia where construction projects such as tilt-up can easily be carried out without problems of mobility.

More than half (66%) of the respondents believed that the economic capability of the Zambian construction industry was likely to be a limitation to the adoption of tilt-up concrete construction in Zambia. 13.9% remained neutral and the remaining 19.5% stated it was unlikely to be a limitation. Given that, the adoption of other modes of modular construction such as prefabs have been slow in Zambia, due to economic reasons this could also be inferred on the use of tilt-up concrete.

4.6. Discussion

The construction industry in Zambia is heavily reliant on concrete block walls (masonry construction) and in-situ concrete walls for wall construction. This normally results in delays and cost overruns. There has been a slow up take of other construction methods such as use of prefabricated panels for commercial wall construction. There was no evidence of use of tilt-up construction in practice. The existent literature provides some evidence that tilt-up construction is faster and cheaper compared to conventional methods of wall construction (Urmson et al. 2013). However, in the Zambia Construction industry the method was found to be fast but not cost effective contrary to findings in the South African construction industry where both time and cost targets were achieved (YN Construction, 2015). The cost aspect comes in due to the high cost of equipment in form of cranes and lack of persons with expertise in tilt-up construction meaning that this expertise would have to be imported.

Other impediments identified were lack of building regulations on the use of tilt-up construction and economic capacity of the country. The case studies had countries such as South Africa, and the USA, in comparison to Zambia these economies are larger and have gone on to encompass technology in construction such as the use of prefabrication panels. Situational impediments noted were location of the site in terms of space. Sites in large spaces were considered suited for tilt-up construction while those in confined spaces were not.

5. Conclusion

Commercial buildings can be constructed using various materials and methods. In the Zambian construction industry, the common walling includes in-situ concrete, and masonry walls (block or brick wall). These tend to be slower in the construction process but cheaper compared to tilt-up concrete construction. Therefore, tilt-up can only be used when the time is of much significance than cost. However, the ZCI lack sealant experts for tilt-up with other requirements needed for tilt-up construction such as professionals in welding and steel reinforcement, crane operator, lifting accessories specialist and joint specialist being readily available. Other possible challenges and limitations associated with tilt-up found in the building sector in Zambia are poor industry knowledge, lack of building regulations for tilt-up construction, inadequate space on site and weather delays. The study could be generalized to commercial building projects in a construction industry in a developing context similar to the set up in the Zambian building sector. This study only focused on tilt-up for commercial building walls other components could be considered for future research.

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