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Stakeholders Perception of the Advantages and Hindrances to the Adoption of Off-Site Production in the Ghanaian Construction Industry

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Abstract
The overreliance on the traditional construction methods by stakeholders of the Ghanaian construction industry has over time failed to adequately meet the needs and aspirations of most clients. This is as a result of their inability to achieve value for money due to time and cost overrun, as well as poor quality of finished products among other problems. It is therefore necessary to study how incorporating Off-site production (OSP) into the Ghanaian construction industry will help solve these problems. The aim of the study is to assess the advantages and hindrances to the adoption of OSP by stakeholders of the Ghanaian construction industry. The scope of the study was limited to key stakeholders in the Ghanaian construction industry in Accra and Kumasi. Questionnaires were sent to 120 key stakeholders. The study established that the major hindrances are the generally low familiarity of the concept of OSP and the low level of mechanisation of the Ghanaian construction industry. Respondents however indicated the main advantages will be the reduction in construction cost and time as well as an increase in the efficiency and quality of the finished products (buildings).
Keywords: Off-site production, Ghanaian construction industry, Advantages, Hindrances

1. Introduction

The traditional construction methods have over time failed to satisfactorily address the vital criteria for buildings in terms of time, cost and quality (Goulding et al., 2012, Hampson and Brandon, 2004 and Goodier and Pan, 2010). Due to this, over the past few decades, the construction industry in several nations has experienced meagre performance and low productivity (Nadim and Goulding, 2010). According to Richard (2005) the building industry has yet to experience an absolute phase of industrialization. He stated that if a car was produced the way a building is delivered, only a few people would be able to own one and that if a computer was produced the way a building is delivered, it would cost a fortune. The solution often suggested to mitigate poor time, cost and quality in construction is to produce buildings in an automated and industrialised environment (Duc et al., 2014). Many methods have been applied to make construction industry more productive. The main focus is on reduction of total duration, reduction in construction cost, improvements in the quality, reducing material waste, achieving more sustainable development, and safer construction sites. One recommended way of improving the construction industry is to move value adding activities off-site, to a more industrial environment (Eriksson et al., 2013, Gibb and Isack, 2003, and Khalfan and Maqsood, 2014). Off-site production (OSP) methods have played a significant part in the construction industry in the past few decades. It is increasingly becoming a key alternative method to traditional in-situ method (Alazaz and Whyte, 2014). Eventhough the use of OSP is seen as a viable means of increasing the level of sustainability with respects to its significant economic, environmental and social contributions, there have been very few studies to date into OSP within the context of developing countries where the places have crucial demands for accommodations (Zhai et, al., 2013). This has necessitated the need to seek stakeholders perception of the advantages and hindrances to the adoption of off-site production in the Ghanaian construction industry

2. Off-site Production

Off-site Production (OSP) involves moving some parts of the construction process to a controlled environment (factory), with the aim to achieve better quality, less time on projects, less cost and reduced risk in the construction of buildings. (Arif et al., 2012; Gibb & Isack, 2003). OSP involves the assembly of pieces in a factory, followed by the transportation of the assembled components to its permanent location and the final fit up. OSP reduces the hazard level of a task in two ways. Firstly, it allows the work location to be shifted to a lower hazard environment where risk associated with working at heights or in confined spaces are reduced; and secondly, it allows the work to be shifted from the construction site to a factory, which allows for the use of safer, automated equipments (Toole and Gambatese, 2006). In order for the concept of OSP to be widely approved and implemented on site to the benefit of the client as well as the design team, care must be taken by the design team to consider the technique at an early stage of design (CIRIA 2003). The prefabrication of components, elements, or even entire structures off-site as an alternative to working in-situ has been extensively

applied in the past, although recently developed approaches have led to a more refined and better developed practical application. The quality of the final product is dependent on both the materials used and attention to details as it does on the construction method (Holroyd (2003). From an occupancy view point, OSP in the construction process can add a lot of value to a project, as seen in a balance of lower time; optimum cost and high quality. (Gibb and Isack, 2003).

Technological advancement allow concepts like OSP to address many of the problems facing the construction industry, such as a shortage of labour skills and the need for greater client involvement (CIRIA, 1999). The use of OSP eliminates or reduces many traditional construction work task with serious risk factors (Simonsson and Rwamamara, 2007). Gibb (2000) further suggests that permanent works designers could reduce the risk by reducing the amount of work done on the construction site, mainly through increased use of some form of preassembly. A major reason posted for the reluctance among clients and contractors in adopting OSP is that they have difficulty ascertaining the benefits that such an approach would add to a project (Pasquire and Gibb, 2002). The use of OSP, by many of those involved in the construction process, is poorly understood and based on anecdotal rather than data supported intelligence (CIRIA, 2000). Some view OSP as too expensive to justify its use, whilst others view OSP as the panacea to the ills of the construction industry's manifold problems (Gibb, 2001). The benefits of OSP directly or indirectly lead to health and safety of the construction worker and should be considered at the design stage. According to Chandler (2014), the Australian construction industry needs to go off-site in order to drive the costs down by at least 20 per cent and durations down by at least 50 per cent in the medium term with significant improvements in construction quality and on-site safety. However, according to Pan and Sidwell (2011) the economic issues in offsite production including the large initial capital outlay and hard-to-achieve economies of scale are perceived by industry practitioners as significant barriers.

Currently in Ghana, there is an estimated population of 27 million, with a growth rate of about 2.2%. Housing requirement by 2020 stands at 5.7 million new rooms. To successfully address the housing deficit, 3.8 new rooms must be completed in every minute of the working day for ten years (UN Habitat, 2011). The housing deficits and the need to provide over a million new houses to meet the national housing needs of Ghanaians all point to the fact that such an approach (OSP) is needed in the country's construction industry. This is because the traditional construction method has led to delays and cost overrun in construction projects which is having a negative effect on the credibility of the Ghanaian construction industry to deliver optimum value for their customers´ investment. There are reports that in Ghana, clients of the construction industry continue to complain about the industry's performance and its seeming inability to deliver projects on time, within budget and to expected quality standards (Nicco-Annan, 2006). In view of such problems, in comparing traditional on-site production to OSP, Meiling et al. (2012) indicated the latter has many advantages such as higher productivity, lower production cost, higher quality and better on-time delivery, to name a few. According to Blismas and Wakefield (2009) OSP because it results in a shorter construction period will lead to quicker return on investment to the client and reduced overhead.

3. Research Methodology

The research adopted the mixed method approach which involves literature review, questionnaire survey, semi-structured interviews, and case study. such an approach permits researchers to address more complicated research questions and attain higher reliability and validity of the research (Yin, 2009). Data gathering was limited to Accra and Kumasi, where major construction activities are centred in Ghana. Questionnaires were sent to 120 stakeholders in the Ghanaian construction industry such as Real Estate developers, Architects, Quantity Surveyors and Civil Engineers. Manufacturers and suppliers of off-site produced building components were also targeted as they are all knowledgeable and qualified enough as respondents for the study and also because they are the target group whose activities will help in the acceptance of the concept of OSP. 75 of the questionnaires were returned**.** In order to validate the questionnaire results, the research was supplemented by interview. Twenty-five people in the target group were consulted. The open discussions centred on OSP systems, problems and solutions in the construction sector and answers that arose during the discussions and interviews were noted. The study also involved site visits to supplement the interview data. The outcomes of the questionnaire survey were mapped against the findings of the site visits and interviews. The random sampling technique (stratified) taking into consideration the respondents' technical background and years of experience in the Ghanaian construction industry as well as the region one was based in was used for the data collection. Snow ball sampling was also utilized in the selection of the Real Estate developers.

3.1 Data Analysis Tools

Three different analytical tools were used in analyzing the responses from the survey. These are Regression

analysis, Importance Index and Pearson's Product Moment Correlation Coefficient. The importance index was adopted from Lim and Alum (1995). A ranking of Importance indices were done to ascertain the most frequent factors. The use of the Importance index facilitates the identification of tactical approaches towards identifying the advantages and hindrances towards the adopting OSP. It gives an analytical explanation of the critical effect of the various factors of the questionnaire. It further gives the aggregate effect and significance to it. The nearer the value of importance index is closer to unity (1), the more significant the various factors have on adopting OSP in the Ghanaian construction industry. Hence attention needs to be directed towards the effects of such factors.

Importance index (I.I) = $\frac{5n1 + 4n2 + 3n3 + 2n4 + n5}{5(n1+n2+n3+n4+n5)}$

(Where: n_1 = "Extremely Significant", n_2 = "Very Significant", n_3 = "Significant", n_4 = "Fairly Significant" and n_5 = "Least Significant").

Pearson's Product Moment Correlation Coefficient was also used to find a correlation between at least two continuous variables. It is used when both variables are at least at interval level and data is parametric. The t test (r) is used to establish if the correlation coefficient is significantly different from zero, and hence that there is evidence of an association between the two variables. Positive correlation indicates that both variables increase or decrease together, whereas negative correlation indicates that as one variable increases, so the other decreases and vice versa.

4 Data Analysis

4.1 Advantages of Adopting OSP

Twelve advantages of applying OSP identified by earlier researchers and relevant to the Ghanaian construction industry were used for conducting the survey: i) minimise on site operation (better supervision); ii) produce high quality/ integrity of the building; iii) reduce overall construction costs; iv) minimise number of site personnel; v) shorten construction time; vi) increase efficiency; vii) improve health and safety; viii) improve environmental performance; ix) aesthetic issues on the building; x) ease in placement; xi) enables existing business continuity xii) reduces congested work area and multi trade interfaces (Zhai, et al., 2013; Tam et al., 2007 and Gibbs and Isack, 2003). For each beneficial factor, the respondents were requested to judge the significance level by selecting one of five grades, that is, least significant to extremely significant. The survey results are summarized to examine the relative levels of the significance among these factors on the benefits in the adoption of OSP; an alternative approach is used to calculate the Importance Index.

Regression analysis was conducted to examine the association between respondent's rate of recommendation and the factors that influence the respondent in using prefabricated component. The result of the correlation analysis between the response and the explanatory variable indicate that there is strong correlation (R = 0.983). Hence recommendation rate of prefabricated component is used as dependent variable and factors that affect the use of prefabricated component are used as independent variables. The result of the model was found to be significant as p-value is 0.0000. This indicates that there is a significant association between the dependent variable and the independent variables. Therefore the overall model explains professional recommendation of prefabricated components use. According to Table 1, the majority of the explanatory variables are significantly associated with the professionals' recommendation of prefabricated component use except '**minimise number of site personnel**' (0.189) and '**reduced congested work area and multi trade interfaces**' (0.211). This indicates that these two factors are not considered by construction professionals when it comes to their recommendation of off-site produced building components. Hence the research has identified the other ten factors that are advantages towards the adoption of OSP as significant factors that affect the construction professionals recommendation of off-site produced components use.

Table 1: Regression: Factors That Influences OSP Usage And Rate of Recommendation

COEFFICIENTS					
	Unstandardized Coefficients	Std. Error	Standardized Coefficients Beta	T-Statistics	P-Value
(Constant)	-2.822	0.392		-7.196	0.00
Minimise on site operation	2.085	0.089	1.372	23.322	0.00
Produce high quality building	-0.401	0.049	-0.459	-8.167	0.00
Reduce construction cost	0.492	0.048	0.543	10.333	0.00
Minimise number of site personnel	**-0.07**	**0.053**	**-0.087**	**-1.333**	**0.189**
Minimise construction time	0.667	0.086	0.755	7.74	0.00
Increase efficiency	-0.673	0.072	-1.084	-9.377	0.00
Improve health and safety	0.513	0.088	0.788	5.821	0.00
Improve environmental performance	-1.432	0.087	-1.885	-16.528	0.00
Aesthetic issues	0.261	0.06	0.516	4.345	0.00
Ease of placement	0.237	0.056	0.318	4.263	0.00
Enables existing business continuity	-0.326	0.089	-0.443	-3.657	0.001
Reduces congested work area and multi trade interfaces	**0.104**	**0.082**	**0.16**	**1.268**	**0.211**
ANOVA TABLE					
	Sum of Squares	df	Mean Square	F	P-value
Regression	31.995	12	2.666	122.972	0.00
Residual	1.084	50	0.022		
Total	33.079	62			
MODEL SUMMARY					
R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	
.983	0.967	0.959	0.147	1.54	

The advantages in applying OSP are considered as having different levels of significance in the Ghanaian construction industry and the major focus of the survey was to identify the level of recognition of these beneficial aspects. Twelve advantages of applying OSP identified by earlier researchers were used for conducting the survey. The results are as portrayed in Figure 1. Respondents ranked minimising construction cost as the most significant factor (0.86) that the adoption of OSP in the Ghanaian construction industry will help address. However, the study indicated that reduction in construction cost does not necessarily mean an increase in the efficiency of the end product and the integrity of the building. Due to the fact that most components will be manufacture under factory conditions, respondents also indicated the construction time will be minimised significantly and thus ranked it second with an importance index of 0.77. The study indicated that a reduction in construction time has an influence on improvement in the health and safety of workers. The research significantly established there is not much difference between "reduction construction time" and "reduction in cost" as far as the need to adopt OSP in the Ghanaian construction industry is concerned as respondents believe these two factors greatly complement each other.

Most respondents also share the view expressed by Toole and Gambatese (2006) that OSP increases efficiency and it is therefore not surprising that respondents ranked it third with an importance index of 0.76 (Figure 1). Respondents according to the study also view the introduction of OSP as a means to the production of high quality buildings. It is ranked a joint third with “increased efficiency” with an importance index of 0.76.

The respondents indicated that the adoption off-site produced building components in the Ghanaian construction industry will results in an increase in productivity, efficiency and quality of building products and help address the assertion by Nicco-Annan (2006) that clients of the Ghanaian construction industry continue to complain about the industry’s performance and its seeming inability to deliver projects on time, within budget and to expected quality standards. He observed time overruns of between 12-24 months and cost overruns of between 60% - 180%, not taking inflation into account. This is having an adverse effect on the credibility of stakeholders in Ghanaian construction industry to deliver optimum value for their customers’ investment.

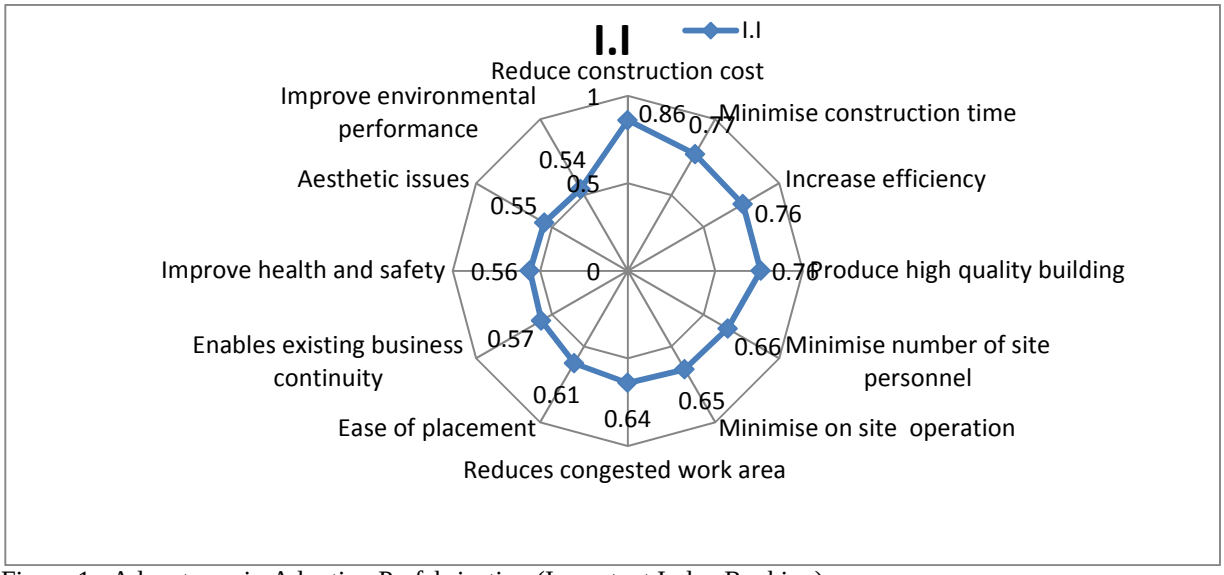

Figure 1: Advantages in Adopting Prefabrication (Important Index Ranking)
Source: Field Survey, February, 2013

Minimise number of site personnel is ranked fifth with an importance index of 0.66. Respondent stated that one major problem facing the nation's construction industry is the quality of qualified construction workforce who have the knowledge base in OSP techniques. Therefore if the site personnel are reduced, it will take a very significant increase in the training of the local workforce in new technologies in construction such as the ease of placing prefabricated components among others to significantly decrease construction time or cost irrespective of the adoption of OSP. It is a fact worth stating that the adoption and proper use of the concept of OSP will speed up the construction process immensely as on-site operations will be reduced to the barest minimum. The study indicated that, when on-site operation is very significantly minimised and the use of off-site produced building components are highly maximised, it will significantly improve housing delivery in the Ghanaian construction industry.

4.2 Hindrances in Adopting Off-site Production

In addition to the advantages in adopting OSP, the hindrances to its adoption were also investigated. Nine hindrances identified by earlier researchers were assessed; i) inflexible for changes of design; ii) higher initial construction cost; iii) time consuming in the initial design development; iv) limited site space for placing prefabricated building components; v) lack of experiences on the contractors; vi) monotone in aesthetics issues vii) leakage problems at joints of prefabricated components; viii) inadequate background research information; ix) lack of demand for offsite produced (prefabricated) components (Zhai, et al., 2013and Tam et al., 2007). Similar to the analysis on the advantages of prefabrication, five significant levels, were used to assess the variables.

Regression analysis was used to examine the association between respondent's rate of recommendation and the factors that influence the respondent in using OSP. The result of the correlation analysis between the response and the explanatory variable indicate that there is strong correlation(R = 0.672). Hence recommendation rate of OSP is used as dependent variable and factors that hinder the use of OSP are used as independent variables. The result of the model was found to be significant as p-value is 0.0000. This indicates that there is a significant association between the dependent variable and the independent variables. The overall model showed that the factors under consideration as hindrances towards the adoption of OSP are significant, This means that, majority of the explanatory variables were significantly associated with the professionals' recommendation of prefabricated component use. The model (Table 2) identified **Monotony in aesthetics** as the only factor that is not a serious hindrance considered by construction professionals in their recommendation of off-site produced building components.

Table 2: Regression analysis of hindrances to the adoption of OSP

MODEL COEFFICIENTS					
	Unstandardized Coefficients	Std. Error	Standardized Coefficients Beta	t-Stats	P-Value
Inflexibility for changes in design	-0.006	0.119	-0.008	-0.051	0.959
Higher initial construction cost	0.224	0.181	0.385	1.239	0.22
Time consuming in initial design development	0.352	0.228	0.451	1.544	0.128
Limited space for placing components	-0.011	0.1	-0.017	-0.114	0.91
Lack of experience on the part of contractors	0.058	0.131	0.098	0.442	0.66
Monotony in aesthetics	**0.343**	**0.12**	**0.567**	**2.861**	**0.006**
Leakage problem at joints of components	-0.17	0.113	-0.286	-1.507	0.137
Inadequate background research information	-0.25	0.151	-0.603	-1.659	0.102
Lack of demand for OSP	-0.189	0.136	-0.368	-1.388	0.17
ANOVA TABLE					
	Sum of Squares	df	Mean Square	F	P-Value
Regression	15.518	9	1.724	5.686	.000a
Residual	18.801	62	0.303		
Total	34.319	71			
MODEL SUMMARY					
R	R Square	Adjusted R Square	Std. Error of Estimate	Change Statistics	
				R Square Change	F Change
.672a	0.452	0.373	0.551	0.452	5.686

According to the importance index ranking (Figure 2), "Higher initial cost" was viewed by respondents as the most significant factor that is hindering the adoption of OSP in the Ghanaian construction industry. Thus it was rated first with an importance index of 0.75. This goes to buttress the views expressed by Gibbs (2001) that many view the approach as too expensive to justify its use. However, according to Cole (2003) while initial cost seems greater with OSP there appears to be a lack of awareness of the possible cost savings over the whole-life of off-site produced products. The study indicated that stakeholders of the Ghanaian construction industry are reluctant to adopt OSP for construction projects because of the fear of "Inflexibility for changes in design" which was ranked second by respondents on hindrances of adopting prefabrication with an importance index of 0.73. To help address this problem, designers must spend time to solve all the design problems at the design conception stage as the true worth of OSP can only be fully appreciated when the choice to use it is taken before design commences. In this way design and construction processes can be developed together in order to maximise its advantages.

Respondents also believe there is the need to educate the local construction workforce on the assembling of building components to make the adoption of OSP a success. Due to this, respondents ranked lack of experience on the part of construction professionals as the third most significant hindrance affecting the Ghanaian construction industry in its quest to adopt the use of OSP. The research indicated that due to the fact that most of the local construction workforces are not very well educated and their knowledge of OSP is very low, it is having a negative effect on the adoption of OSP.

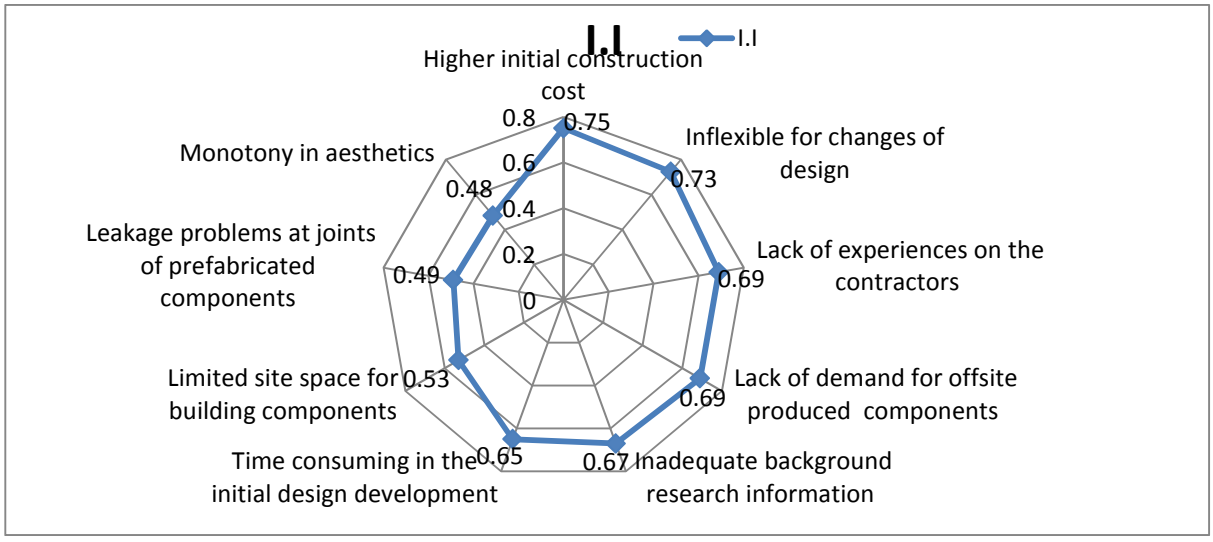

Figure 2. Hindrances in adopting OSP (Importance Index Ranking)
Source: Field Survey, February, 2013

Many respondents view "Lack of demand for prefabricated components" as another major problems hindering the adoption of OSP, thus it is ranked a joint third with an importance index of 0.69. Respondents stated that lack of demand for prefabricated components is brought about by the perceived problems of higher initial construction cost with the use of prefabricated components as well as the inexperience on the part of the local workforce. This coupled with the lack of adequate information on the use of prefabricated building components on the part of both professional and other stakeholders of the Ghanaian construction industry has led to disinterest in the adoption of OSP as against the traditional in-situ construction.

5. Conclusion

Some peculiar problems exist in the Ghanaian construction industry against the application of OSP. The study established that the major hindrances include the generally low familiarity of stakeholders of the Ghanaian construction industry with the concept of off-site production. Secondly, the low level of mechanisation and construction technology in Ghana does not support the use of OSP. However, the resultant early completions, user satisfaction, ease of maintenance and replacement all points to the fact that OSP has great potentials. Respondents indicated that the main advantages in the adoption of OSP will be the reduction in construction cost and time as well as increasing the efficiency of the end products. It can therefore be stated that though not widely used in the Ghanaian construction industry, most stakeholders believe that in the near future, OSP will be the way forward for the industry, especially where Real Estate development is concerned due to the repetitive nature of building construction in this field. This is because it will help in cost reduction and early completion as well as achieving value for money to clients.

6. Recommendations

The conditions to be met to make OSP attractive and acceptable include adequate research information and interest in the use of off-site produced components, adequate training of the local construction workforce and mass production of off-site components. There should be ongoing studies and sensitisation of the concept among the academia and stakeholders of the Ghanaian construction industry. But all these notwithstanding, the current trend of globalisation offers a lot of opportunities for the Ghanaian construction industry as far as systems and techniques that support a smooth implementation of the concept of OSP is concerned. Stakeholders of the Ghanaian construction industry must also take advantage of the presence of construction and consultancy firms from various parts of the world in Ghana to learn from them new construction practices such as OSP. Some limitations associated with the practise of OSP in the Ghanaian construction industry stems from some perceived peculiar characteristics of the industry compared to the manufacturing industry. Standardising building components is one strategy for a successful implementation of off-site production in the Ghanaian construction industry.

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