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Barriers to the Uptake of Concurrent Engineering in the Nigerian Construction Industry

Regular Paper

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Abstract It is the consensus of scholars that the productivity of the construction industry is very low when compared with other industries. Concurrent Engineering (CE), which has a primary goal of reducing the total time from designing a product to releasing it into the market, while creating better designs as well, has been identified as one of the concepts that has yielded effective adaptation in the construction industry. An exploratory survey was used to identify 63 variables with the capacity to influence the uptake of Concurrent Engineering in Nigeria and was used to design a questionnaire, which was distributed to 50 stratified construction industry stakeholders. A statistical software package (STATISTI-XL) was used to analyse the severity index of each variable, in order to establish the importance of each variable in influencing the uptake of Concurrent engineering and also to compute the Kendall's coefficient of concordance, which assess the levels of agreement among the judges on the consistency of the rankings. A Kendall's coefficient of concordance of W=0.57365 was recorded. A lack of awareness emerged as the most important barrier against the integration of this concept into the Nigerian construction industry. The top five variables are all human factors that can be ameliorated by proper education.

Keywords Developing Countries, Concurrent Engineering, Kendall's Coefficient of Concordance, Severity Index

1. Introduction

The construction industry generally has been faced with continuously increasing and sophisticated demands, which call for the most efficient use of the available resources. Many of the services and parts of the structure of modern facilities are now so technically specialized that they have to be designed by many specialists. In response, the construction industry has evolved, with the fragmentation of the production responsibilities into many sub-processes split amongst many participants, who belong to different organizations with different policies, objectives and practices (Aniekwu, 2002). This increases the channels of communication necessary in the design and production processes. The atmosphere created under these circumstances is one of rivalry, bureaucracy, distrust, suspicion, misunderstanding, buck passing, etc. In this situation, the project team is reluctant to make any decision that deviates from drawings or specifications, even if it is an improvement. There is no incentive to improve the process and, needless to say, the resources are not optimized.

Successive National Governments and institutional reports have examined the activities of the construction industry and have commented upon the need for improvement; Simon 1944, Phillips 1950, Emmerson 1962, Bowley 1963, Banwell 1964, Higgins and Jessop 1965, Bishop 1972, Munday 1979, Ball 1980, NEDO 1978, 1983, 1988, Kirmani 1988, British Property Federation 1983, Latham 1993, 1994 and DETR 1998. The reports identified, amongst other factors, the fragmented nature of the construction process and industry (evident in the large number of firms operating within it), the distinct separation of the professions, poor communication, a lack of concurrency, institutional barriers, ad hoc problem solving approaches, lack of trust and collaborative spirit within the client/design/construction team as responsible for the consistently low levels of performance.

Attempts have been made to integrate construction design and production processes through the use of various procurement strategies, such as design and build, fast tracking, project management etc. (Fellows, 1997). Practitioners and researchers have turned to the manufacturing industry as a point of reference and source of innovation. Accordingly, a concept known as CONCURRENT ENGINEERING (CE) has become the focal point of research. This concept advocates the use of a multi-disciplinary project team, whereby participants are brought together during the design stage to determine how downstream issues may be affected by design decisions.

While these problems may be the same the World over, the direct consequence in the global south is a lack of capacity of local industries to implement their national construction objectives, thus relying on foreign skills and technologies. Similar problems in the manufacturing sector have been overcome through the introduction of CE in place of serial or sequential project delivery method (Fig. 1).

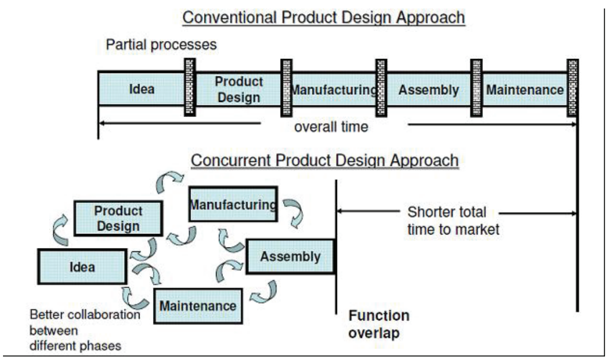


Figure 1. Conventional product design approach.

The need for adopting concurrent engineering in construction is discussed in several publications (de la Garza et al. 1994, Eldin 1997, Love and Gunasekaran 1997, AbulHassan 2001) and their contributions are summarized as follows:

- CE is a philosophy that can overcome the disadvantages of existing fragmentation and specialization in the construction industry, if applied properly (de la Garza et al. 1994).
- CE is a scheduled reduction tool that could reduce project delivery duration by 20-25% without an associated increase in project cost (Eldin 1997).
- CE is an approach imported from the manufacturing industry to assist in overcoming the construction industry's poor productivity and performance (Love and Gunasekaran 1997).
- CE application in a construction project tended to increase project delivery speed and project quality without a significant impact on project unit cost (AbulHassan 2001).

Countries of the global south, more than any other, are in need of new approaches in project delivery to enhance the capacity of their industries and to deliver their national goals

2. Concurrent Engineering

The term Concurrent Engineering was coined in the late 1980s to explain the systematic method of concurrently designing both a product and its downstream production and support processes (Evbuomwan and Anumba 1995, Huovila et al. 1997). It was proposed as a means to minimize product development time (Prasad 1996). This was necessitated by changes in: manufacturing techniques and methods, management of quality, market structure, increasing complexity of products and demands for high quality and accelerated deliveries at reduced costs. These changes resulted in a shift in corporate emphasis, with the result that the ability to rapidly react to changing market needs and time-to-market, became critical measures of business performance (Constable 1994, Thamhain 1994).

Cleetus, J. of West Virginia University's Concurrent Engineering Research Centre defined concurrent engineering as "*a systematic approach to the integrated development of a product and its related processes—from conception to disposal—that emphasizes response to customer expectations and embodies team values of cooperation, trust and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives, synchronized by comparatively brief exchanges to produce consensus*" (CERC Homepage 1998).

In the context of the construction industry, Evbuomwan & Anumba (1998) defined Concurrent Engineering as "*an* *attempt to optimise the design of the project and its construction process to achieve reduced lead times and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximising concurrency and collaboration in working practices*", This is in sharp contrast with the traditional approach to construction project delivery. Concurrent Engineering is a departure from the traditional sequential approach to product development and thus requires a new design environment and technology in order to support the extensive interdisciplinary co-operation and integration inherent in the concurrent approach (Fig.2).

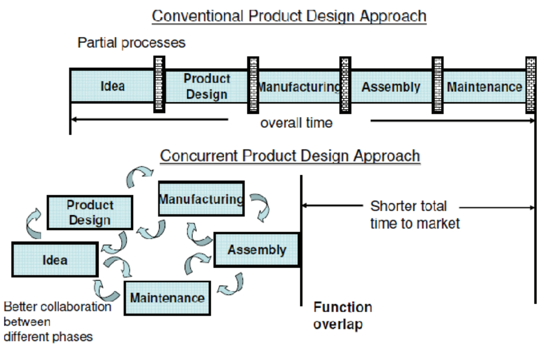


Figure 2. Concurrent Product Design Approach.

The success of CE in manufacturing was one of the main motivations for adopting CE in construction (de la Garza et al. 1994, Anumba and Evbuomwan 1995, Evbuomwan and Anumba, 1995, 1996, Huovila and Serén 1995, Hannus et al. 1997, Kamara et al. 1997, Love and Gunasekaran 1997, Anumba et al. 1999). It is also based on the assumption that because construction can be considered as a manufacturing process, concepts that have been successful in the manufacturing industry can bring about similar improvements in the construction industry. Furthermore, the goals and objectives of CE directly address the challenges that currently face the construction industry.

3. Research Methodology

The theoretical framework for this study is adopted from the national readiness index methods, which was developed at INSEAD (Kirkman et al. 2002, Dutta 2002). It assesses the extent to which the construction industries environment in the global south can encourage the uptake of new technologies and innovations based on the following four key components, each of which is further broken down into relevant factors with many variables:

1. **Environment** as a crucial enabler of all developments.
2. A multi-stakeholder effort and **capacity** to innovate.
3. The willingness to innovate will lead to **usage** and increased impact.
4. **Culture** as the glue that binds all developmental efforts together and creates the value system for all judgments.

4. Environment Components

An innovation-conducive environment is a key prerequisite for stakeholders in a given economy to lever new developments, such as CE, for enhanced growth. The business environment of any industry constitutes the atmosphere in which all the industry transactions are carried out. They consist of tangible and intangible systems and structures, which affect and regulate the relations, actions and interaction of all the participants of that industry. This component is analysed under the following four factors:

- Market Environment (16 Variables)
- Political and Regulatory Environment (8 Variables)
- Construction Infrastructure Environment (14 Variables)
- Security Environment (5 Variables)

Capacity Component

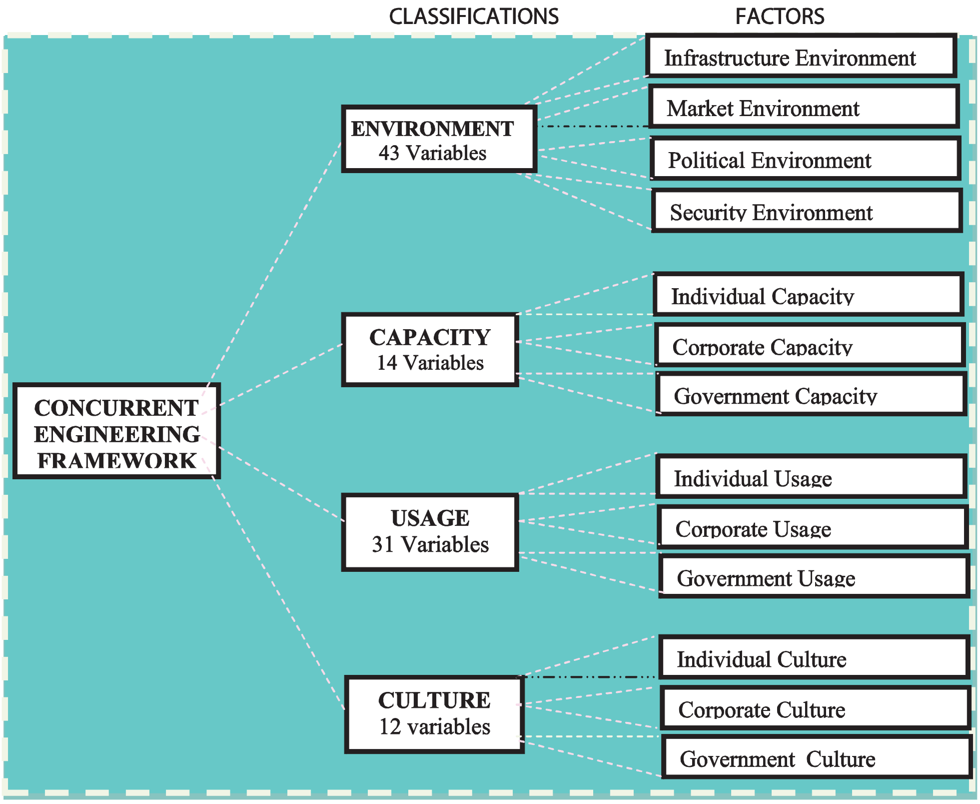
A multi-stakeholder effort is required in the adoption of new technologies. Although the government has a natural leadership role to play when it comes to establishing an innovation-friendly environment and to motivating CE penetration, a multi-stakeholder effort involving the government, the business sector and civil society is required. An effective multi-stakeholder effort can lead to leapfrogging stages of development, to a structural transformation of the economy and to increased growth prospects. The capacity component gauges the preparation and willingness of the stakeholder groups to embrace CE in their daily activities and transactions. The component is further analysed thus:

- Individual Capacity (4 Variables)
- Business Capacity (5 Variables)
- Government Capacity (5 Variables)

Usage Component

The stakeholders who are better prepared and show greater interest towards CE will be more likely to use it more extensively and effectively and will lead to increased impact. This link between enablers and usage/impact comes from prior research in the management literature, where all models of total quality management made an explicit distinction between enablers and results (Insead 2002). This component measures the actual and potential usage of new technologies by an economy's main social actors and can be broken down into the following factors:

- Individual Usage (5 Variables)
- Business Usage (13 Variables)
- Government Usage (13 Variables)



Culture Component

Culture is the code that gives meaning to all of people's actions and acts as the glue that binds all developmental efforts together and creates the value system for all judgments. The ability to communicate and pursue shared goals is hinged on the ability to cross-acculturate. These factors relate to cultural values, which shape the behaviour within the environment in which construction organizations operate. They relate to issues such as the synthesis of attitudes, values, beliefs, behaviours, work ethic, business ethics, attitude to environment, interaction with others, religion and stereotypes that have been passed on or learned. It is about patterns of meaning; it is about shared beliefs, perspectives, and worldviews; it is about shared behaviour, practices, rules and rituals. It is broken down into the following factors:

- Individual Culture (5 Variables)
- Business Culture (4 Variables)
- Government Culture (3 Variables)

63 variables emanating from these components and factors were used to design a questionnaire which was distributed to 50 stratified construction industry stake-holders, including clients, architects, structural engineers, mechanical engineers, electrical engineers, quantity surveyors, contractors, construction material suppliers, specialist subcontractors and developers. The judges were required to rank the variables in their order of importance, with the most important ranked 1 and the least important ranked 63.

The Kendall's coefficient of concordance was used to assess the levels of agreement among the judges, i.e., the consistency of the rankings of the judges. It is a statistical test of agreement among two or more judges, or of the consistency of two or more sets of rankings in a contest. It is a normalization of the statistic of the Friedman test and can be used for assessing agreement among raters. Where the object i is given the rank $r_{i,j}$ by judge number j, where there are in total n objects and m judges. Then the total rank given to object i is

$$R_i = \sum_{j=1}^{m} r_{i,j}, \tag{1}$$

and the mean value of these total ranks is

$$\bar{R} = \frac{1}{2}m(n+1). \tag{2}$$

The sum of squared deviations S is defined as

$$S = \sum_{i=1}^{n}(R_i - \bar{R})^2, \tag{3}$$

and then Kendall's W is defined as

$$W = \frac{12S}{m^2(n^3 - n)}. \tag{4}$$

Kendall's W ranges from 0 (no agreement) to 1 (complete agreement). Where R is the sum of the squared differences from the mean rank and K is the sum of k3 – k. k is the number of tied cases for a particular rank, total *n* = total number of objects and *m* = total number of judges. S = squared deviation.

5. Data Analysis and Discussion of Results

A total of fifty (50) questionnaires were completed and returned and were analysed. Appendix 1 shows the various variables for the determination of Kendall's W; the ranking of the variables with the most important variable ranked "1" and the least important ranked "63". It also shows the relative importance of each of the 63 variables in the implementation of concurrent engineering, as a function of the percentage of respondents who ranked them above average or below average. The number of variables assessed **n=63**, the number of judges **m=24**, the mean value **=837.222**, the sum of squared deviation **S=6883385** and Kendall's coefficient of concordance **W=0.57365**

The Kendall's coefficient of concordance **W=0.57365** indicates that there is fair level of agreement between the judges on the importance of each factor identified, in affecting the uptake of CE into the Nigerian construction industry. The 5 most influential variables are:

1. **Concurrent Engineering Awareness** with a sum of squared deviation of 537312.3
2. **Concurrency in Construction** with a sum of squared deviation of 414756.4
3. **Team Building** with a sum of squared deviation of 327202.2
4. **Effective Communication** with a sum of squared deviation of 262160.3
5. **Contractual Commitments** with a sum of squared deviation of 170582.1

While the 1st and 4th variable emanate from the capacity of stakeholders to adopt CE, the 2nd and 5th variables relate to the adequacy of the infrastructural environment of the construction industry, which can mostly be ameliorated through government intervention. The 3rd most influential variable relates to the cultural acceptance and values that shape the behaviour within the environment in which construction organizations operate. Factors of capacity and culture pertain mostly to the segregated individual, corporate or government deficiency or absence of the knowledge of this concept in the operational environment in the global south. This situation could arise from the deficiency in the quality of training and education in these areas or it could result from the level of importance and acceptability attached to it. This will relate to the readiness of the industry in adopting this concept and can be ameliorated through individual effort and education.

Of the 10 most influential variables, 6 variables are related to the infrastructural environment factor which is intrinsic in the structure of the environment and may require an adjustment to some existing conditions in order to remedy them. 3 variables are related to the stakeholders' capacity factor and 1 variable is related to the cultural factor. However, the 4 most important variables are all related to the core issue of the integration of construction processes.

The five least important variables are listed below

59. **National Legislature – 1159** (Regulatory Environment Factor)
60. **Research/Development Expenditure – 1162** (Capacity factor)
61. **Collaboration with Universities – 1188** (Capacity Factor)
62. **Outsourcing – 1188** (Environment/Capacity)
63. **Virtual Social Networks – 1274** (Usage Factor)

6. Conclusion

The following conclusions can be made from the work reported on the barriers to the uptake of CE into the Nigerian construction industry:

1. Despite some differences in viewpoints held by each professional, there is substantial agreement among them on the variables that can influence the adoption of CE (Kendall's coefficient of concordance **W=0.57365**). All the groups felt that the lack Concurrent Engineering awareness, the absence of the use of Concurrency in construction, difficulties in team building, non-effective communication and weak and unenforceable contract commitments are the most important barriers to the adoption of CE in Nigeria and perhaps in the global south.
2. The most challenging barriers to the uptake of CE in the Nigerian construction industry are environment factors, which relates to the inadequacy of the infrastructure (market, political and regulatory), as well as the security environment to support the implementation of CE. They are intrinsic to the structure of the environment and may require the adjustment of some existing conditions and institutions in order to remedy them.
3. Improved formal or informal education strategies for all stakeholders would perhaps affect this situation positively more than any other remedies and can have both short and long term effects.

The study is part of an on-going research and has presented the subjective results of a study of a stratified group of professionals in the Nigerian construction industry and therefore should not be taken as an absolute statement of the true barriers to the adoption of CE in the Nigerian construction industry. However it is hoped that results may have contributed to the debate in this area.

7. Appendix 1

S/No/ RANK	VARIABLES	*R*		()	()²	% Of Respond who ranked above average
			∑=5831504.2			
1	Concurrent Engineering Awareness	41	774.016	630788.9	537312.3	100.0
2	Concurrency in Construction	130	774.016	13276.16	414756.4	100.0
3	Team Building	202	774.016	193795.6	327202.2	95.8
4	Effective Communication	262	774.016	9845.049	262160.3	95.8
5	Contract Commitments	361	774.016	69285.94	170582.1	87.5
6	Corrupt Practices	387	774.016	15183.72	149781.3	87.5
7	Availability of Professionals	414	774.016	390902.8	129611.4	83.3
8	Management Expertise	416	774.016	156200.6	128175.4	83.3
9	Inadequate Transportation	490	774.016	1312.049	80665.02	79.2
10	Due Diligence	526	774.016	79649.38	61511.87	79.2
11	Delayed Remuneration	537	774.016	300547.6	56176.52	75.0
12	Power Supply	550	774.016	248.9383	50183.11	75.0
13	Inter-personal Relationship	580	774.016	68237.05	37642.16	75.0
14	Material Supply Chain	596	774.016	9845.049	31689.65	70.8
15	Motivation of Workers	631	774.016	13276.16	20453.54	62.5
16	Financial Market Sophistication	645	774.016	13046.72	16645.1	62.5
17	Telephony	655	774.016	12718.83	14164.78	62.5
18	Unforcastable Workload	661	774.016	156200.6	12772.59	62.5
19	Political Influence	667	774.016	98108.16	11452.4	62.5
20	Lack of Trust	670	774.016	8690.383	10819.3	62.5
21	Materials Scarcity	677	774.016	12945.38	9412.08	62.5
22	Construction Lifecycle	679	774.016	61890.38	9028.016	62.5
23	Fragmentation of Construction Processes	688	774.016	23341.05	7398.73	58.3
24	Educational System	690	774.016	2727.16	7058.667	58.3
25	Venture capital Availability	694	774.016	462702.3	6402.54	54.2
26	Alternative/Backup Power Supply	710	774.016	30702.83	4098.032	54.2
27	Unfair Contract Clauses	715	774.016	15932.05	3482.873	54.2
28	Contract Documentation	725	774.016	36184.49	2402.556	54.2
29	Materials Supplies Logistics	745	774.016	2832.605	841.9209	54.2
30	General Insecurity	749	774.016	8794.272	625.7939	50.0
31	ICT Penetration	762	774.016	167917.8	144.3812	50.0
32	Capacity for Innovation	773	774.016	95.60494	1.031998	50.0
33	Revolving Door Policy	774	774.016	9560.494	0.000252	45.8
34	Lack of Standardization	781	774.016	163395.6	48.77803	45.8
35	Effective Internet Services	799	774.016	37163.27	624.2066	45.8
36	Family Influence	804	774.016	316.0494	899.0479	45.8
37	Import Dependent Market	814	774.016	7018.716	1598.73	45.8
38	Site Security	848	774.016	6925.938	5473.651	41.7
39	Unfavourable Lending Terms	867	774.016	20800.05	8646.048	41.7
40	Beliefs	880	774.016	125867.3	11232.64	37.5
40	Equipment leasing/buying options	880	774.016	42344.49	11232.64	37.5
42	New Technologies	885	774.016	10449.38	12317.48	33.3
43	Government Regulation	899	774.016	6205.938	15621.03	33.3
44	Local Content Policy	928	774.016	166282.7	23711.11	29.2
45	Materials Testing Facilities	940	774.016	565.3827	27550.73	29.2
46	Religious Influence	953	774.016	34885.94	32035.32	25.0
47	State Security	960	774.016	79963.27	34590.1	25.0
48	Importation/Customs Clearances	975	774.016	38721.49	40394.62	25.0
49	Judicial Independence	1011	774.016	38.71605	56161.48	25.0
50	Low Productivity of the Construction Industry	1029	774.016	2325.383	65016.91	25.0
51	Violent Practices	1036	774.016	106131.2	68635.68	20.8
52	Foreign Exchange Policies	1048	774.016	90467.27	75067.3	20.8
53	Taxation	1080	774.016	6925.938	93626.29	20.8
54	Currency Exchange Rates	1084	774.016	76605.94	96090.16	16.7
55	ICT Law	1094	774.016	104832	102389.8	16.7
56	Intellectual Property Protection	1115	774.016	3573.383	116270.2	16.7
57	Research and Development	1136	774.016	147285.4	131032.5	12.5
58	Terrorism	1144	774.016	518.8272	136888.3	12.5
59	National Legislature	1159	774.016	215089.8	148212.8	12.5
60	Research/Development Expenditure	1162	774.016	308888.9	150531.7	12.5
61	Collaboration with Universities	1188	774.016	176213.4	171382.9	12.5
61	Outsourcing	1188	774.016	224465.4	171382.9	12.5
63	Virtual Social Networks	1274	774.016	136735.6	249984.1	12.5

Table 1. Summary of computed results

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