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Abstract

Purpose: Architectural and engineering facilities poses difficult management problems which has left the construction industries with waste and non-value adding activities and the clients have not been able to pull value from projects handled by contractors. It is against this background that this research was carried out for project managers to know how to apply lean construction principles and techniques to deliver their projects without waste, reduce project abandonment and abortion and for effective project delivery.

Material and Methods: The research was carried out using primary and secondary data and subsequently analyzed. The data was presented using tables and charts

Findings: It was observed that the principles of lean construction which promotes, the elimination of waste and non-value adding activities in processes, to engineering and design is unknown to our construction industries. Many of the construction firms are skeptical about the principal ad are not ready to entertain the techniques involved.

Implications to Theory, Practice and Policy: It is recommended that the principle of lean construction be introduced and practiced by the construction firms so they may concentrate on how projects will bring value to the client.

Keywords: *Construction, Engineering, Facilities, Lean, Project, Management*

1.0 INTRODUCTION

Lean construction is the application of lean production principles and processes, which promote the elimination of waste and non-value adding activities in processes, to engineering and design. It considers three perspectives to describe the design processes which are conversion, flow and value generation. The difference in these visions is in the way that they conceptualize the process; in order words, the way in which they describe their aspects and properties. These symbolic representations make them vary from their essential principles to the method and practices to carry out their practical contribution.

The conversion view is instrumental in discovering which tasks are needed in a design undertaking, thus, it is perfectly possible to realize design projects based on this view. The conversion view is however not especially helpful in figuring out how to ensure that customer (Koskela and Houvila, 1994).

In short, the conversion view is effective for management, but not for improvement. In fact, this view only addresses the first of three issues that according to Turner (1993) make up the core of project management:

1. An adequate or enough work done.
2. Unnecessary work not done and,
3. The work that is done delivers the stated business purpose.

Conceptualizing the design process as flow of information leads itself to reducing waste by minimizing the amount of time before information gets used, the time spent inspecting information for conformance to requirements, the time spent reworking information to achieve conformance and the time spent moving information from one design contractor to the next.

Further, and even more important than reducing the cost and time of design, conceptualizing the design process as a flow of information allows co-ordination of interdependence flows and the integration of design with supply and site construction as opined by Ballard et al (1998).

In the value generation model, the emphasis is on obtaining the customer's requirements. The improvement of design lies in reducing the loss of value that arises when not all requisites are transmitted in the process. On the other hand, value consists of product performance and lack of defects.

This value has to be evaluated from the perspective of the next customer(s) and the final customer. To prevent the loss of value, it is necessary to analyze the requirements and need at the outset in close co-operation with application of quality function deployment (QED) and rapid interactions between all of the participants who issue design and construction information Huvila et al. (1997).

Statement of the Problem

The design of architectural and engineering facilities poses difficult management problems. The nature of the design process is complex it involves thousands of decisions, sometimes over a period of years under a highly uncertain environment. The design process fails to minimize the effects of uncertainty and complexity.

The construction industry is then left with waste and no-value adding activities. There is the inability of the client to pull value from the project handled by a contractor without interruptions.

Lack of workflow and labour have led to low productivity and sometimes project abortion and abandonment, sometimes it is low pricing of tender in order to secure the job.

By the application of lean construction principle, can reduce material waste and still achieve quality and construction operation simplified with value.

Purpose of the Study

This study is aimed at introducing lean construction into Nigerian construction sector as it is in developed country.

It will also further reduce the issue of cost overrun by eliminating waste on construction site both material and human waste.

It is aimed at analyzing the role of a project manager in a construction where lean construction principles are applied.

Significance of the Study

The result of this study will help project managers understand the principles of lean construction and its application on a construction project.

It will assist construction industries stakeholders in understanding means of eliminating was during construction project. It will therefore help in detecting certain constraint that will hamper the progress of the project in a developing country like Nigeria. The application of new management thinking, like that of lean production which suggested that better labour and cost performance can be achieved by improving the reliability of flow. It is possible to achieve better productivity through the application of learn construction and management principles. On completion of this study, its significance or importance to the construction industry as a whole is to equip project managers with practical skills or knowledge for successful managing of building and engineering project under the current economic predicament.

Objectives of the Study

The objective of this work is to elaborate on the following:

1. To create awareness of the lean construction techniques.
2. The development of the lean construction principle and fundamentals.
3. To create the idea of managing complexity in the construction industry.
4. To identify the causes of labour inefficiency in the construction industry.

Research Questions

The series of problems observed in the construction industry is due to certain management lapses ad unreadiness to adapt to new techniques in construction.

These questions therefore follow this piece of work:

1. Construction industry/firms are becoming aware of the benefits of lean construction techniques and are interested in its implementation. Is your organization aware of this technique and principle?
2. Does your organization implement this principle?
3. Would your organization be interested to be acquainted with this principle?
4. Is your organization skeptical in adopting this principle?

5. How has your organization been able to manage complexity and labour inefficiency?

Delimitation of the Study

This study on lean construction is carried on some construction industries in Nigeria with reference to Port Harcourt. It is observed that the construction companies contacted are not aware of the principles of construction and its application. The knowledge of the principles and the application of lean construction should be established in our construction firm for better productivity.

Limitations of the Study

The research work is limited since many professionals that were contacted are not knowledgeable in the lean production process and as such were not ready to attempt the questions as regards to the topic. The availability of local materials, concerning the research topic is lacking and there are no facts to adopt concerning lean construction in our firms. All materials and information for the research work are foreign oriented.

Definition of Terms

The following terms have been defined in this text:

1. Lean design- the application of learn production principles which promotes the elimination of waste.
2. Project- sequential linear process which can be planned in any degree of detail and through an adequate effort and executed according to plans.
3. Manger-a person responsible for running an organization.
4. Role-position and function in a situation or society.
5. Construction- the building or construction of something.

2.0 LITERATURE REVIEW

Lean Production

Lean production was developed by Toyota led by Eng. Ohno while the tern learn was coined by the research team working on international auto production to reflect both the waste reduction nature of the Toyota production system and to contrast it with graft and mass forms of production (Womack et al 1991). Ohno followed the work of Henry Ford and continued the development of flow-based production management. But unlike Ford who had an almost unlimited demand for a standard product, Ohno wanted to build cars o customer order. Produce a car to the requirements of a specific customer, deliver it instantly and maintain no inventories or intermediate stores. Failure to meet the unique requirements of a client is waste, as is time beyond instant and inventory standing idle.

The concept of lean production include:

- Identify and deliver value to the customer, eliminating anything that does not add value.
- Organize production as a continuous flow.
- Perfect the product and create reliable flow through stopping the line, pulling inventory and disturbing information and decision making.
- Pursue perfection: deliver on order, products meeting customer requirements with nothing inventory.

Lean Construction (Fundamentals and Principles)

Lean construction accepts the Ohno's production system criteria as standard of perfection. Learn production invites closer look. Certainly, the goal of delivering a project meeting a specific customer requirement in zero time sounds like the objective of every project and the evidence of waste in Ohno's terms is overwhelming.

Partnering makes great sense from an activity perspective but few realize that partnering is a solution to the failure of central control to manage production in conditions of high uncertainty and complexity. Lean supports the development of teamwork and a willingness to shift burdens along supply chains. Partnering relationship coupled with lean thinking make rapid implementation possible.

Labour must be matched with work, i.e., the availability of resources to make a new work without interpretations.

Learn Thinking on Variability

Variability is common on construction projects and must be managed effectively. New thinking, like that of lean production, has suggested that better labour and cost performance can be achieved by reducing output variability. Managing variability is an important dimension of learn thinking. The focus of lean production is on workflow throughout (the flow of work through a process or system) and flexible capacity strategies to manage the difficulties created by production variability.

Workflow Variability in Construction

The application of lean thinking to construction has concentrated on workflow throughout in the construction process. Koskela (1992) described several general principles of lean construction in his work on understanding production flows. According to Koskela variability in the flow of work often extend cycle times and reduces system throughout by increasing the amount of waste in a process. Others have built on this work including Ballard, et al, (1998). These learn principles relate to a broader objective, which is to reduce the wasteful activity in a process as a way to improve the value-adding content

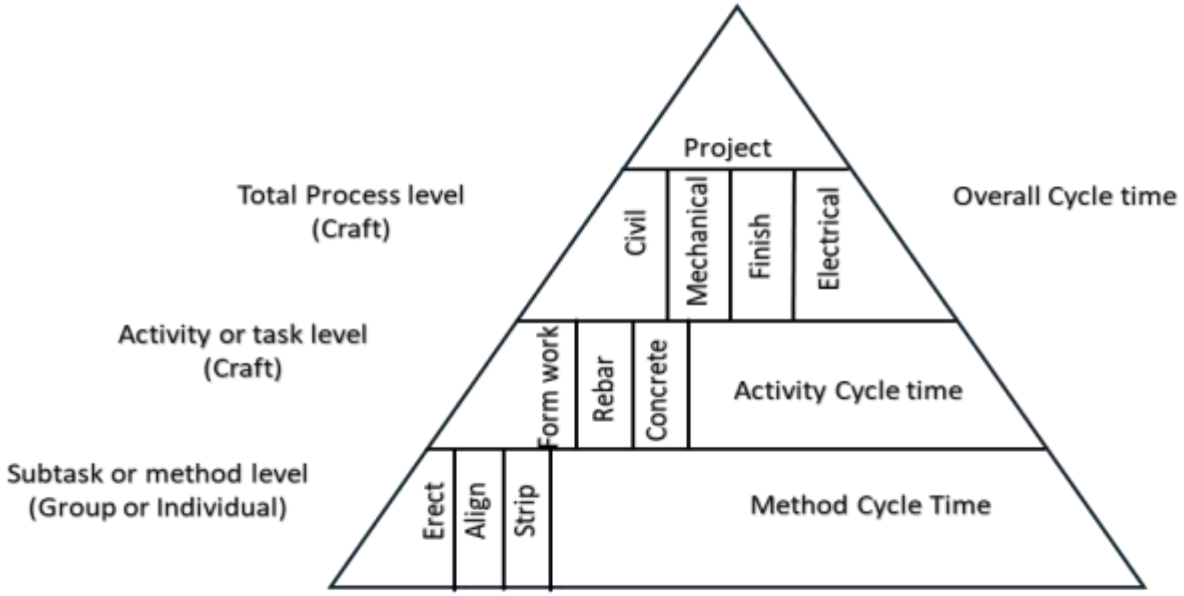

Figure 1: Construction Hierarchy

Improve Flow Reliability

Improving flow reliability means to make sure that adequate resources are available at the right time. When needed resources are not in place, construction is delayed. This affects subsequent tasks by varying the availability of pre-requisite work, exacerbating the problems of subsequent task by making the efficient preparation and availability of resources more difficult. Research has shown that the availability of resources in a significant determinant of good crew or graft performance or labour productivity (Hand and Rivers 1983, Horner and Talhoumi 1993). One of the most common problems in construction is the ability of the contractor to deliver materials at the right time and the right place (Thomas et al 1989, 1999, Thomas and Smith 1990, Thomas and Sanvido 2000).

Equipment flow is another important resource. A problem in some construction operations is poorly maintained equipment or the wrong piece of equipment can also slow the completion of work (Howell et al 1993). Information is another flow-correct, complete and timely information is always a concern in construction.

Eliminate Waste and Simplify Operation

Reducing Waste and simplifying operations should improve system responsiveness and reduce variability. The presence of waste and excessively complex operations make things more time consuming and costly than needed. Waste and complexity contribute to availability by increasing system inertia and making it difficult to respond to different circumstances, thus requiring excessive resources.

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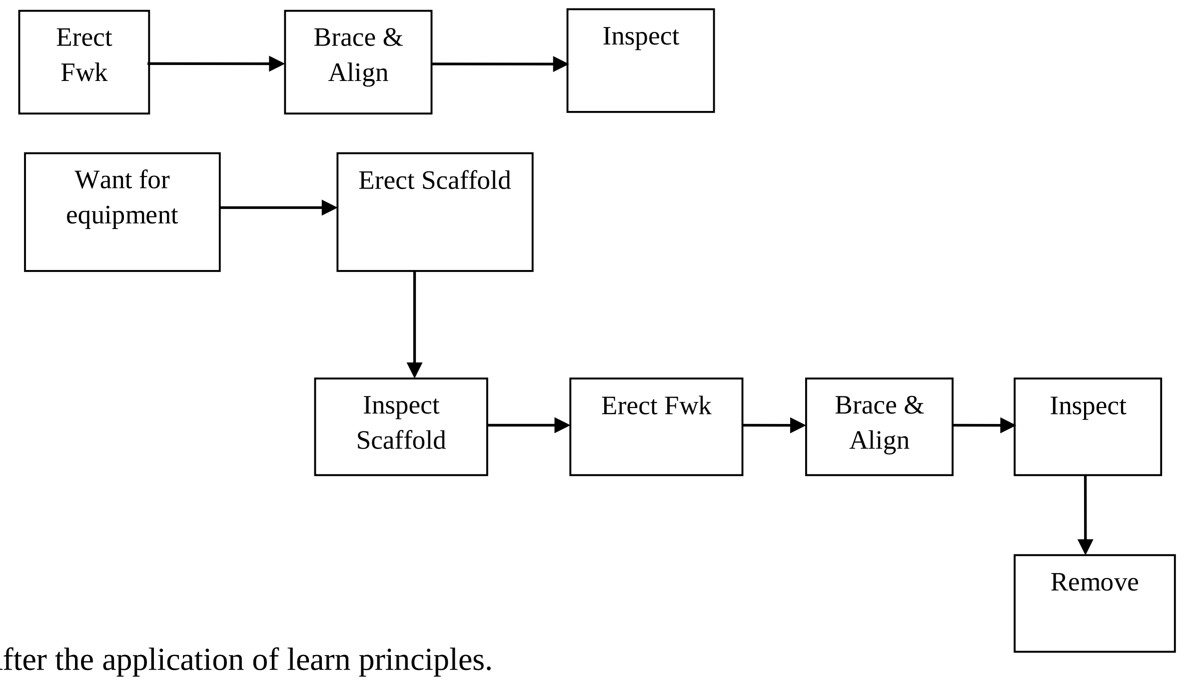
a) After the application of learn principles.



b) After the application of learn principles.

Flexible Capacity Strategies in Construction

The ability to reduce cycle time with measures that improve flow reliability, eliminate waste, and simplify the operation permitted by a flexible approach to labour and resources management called Capacity Management (Horman and Kenley, 1998).

Conceptuality, it is important to complement. Work flow management with flexible capacity management because flexibility that is beyond the control of management, such as erratic customer order patterns, last minute order adjustments and some supply difficulties.

Direct Work as Performance Measure

In lean production, improvements result from increasing proportions of value-added work by reducing the content of waste. In the past, in construction, value-added work has been described as direct work and has been measured with work sampling studies, but one major problem with work sampling is that it only provides information on the input (labour) and none on the output. Thomas (1991) has called into question the usefulness of direct work as a performance measure for this reason.

Factor –Resource Model

The factor –resources model provides a framework to explore the relationship between variability and performance (Thomas et al 1990, Sanders and Thomas 1991). Like Koskela's (1992) new production model, the factor – resources Model expands important dimensions of the standard input process output model.

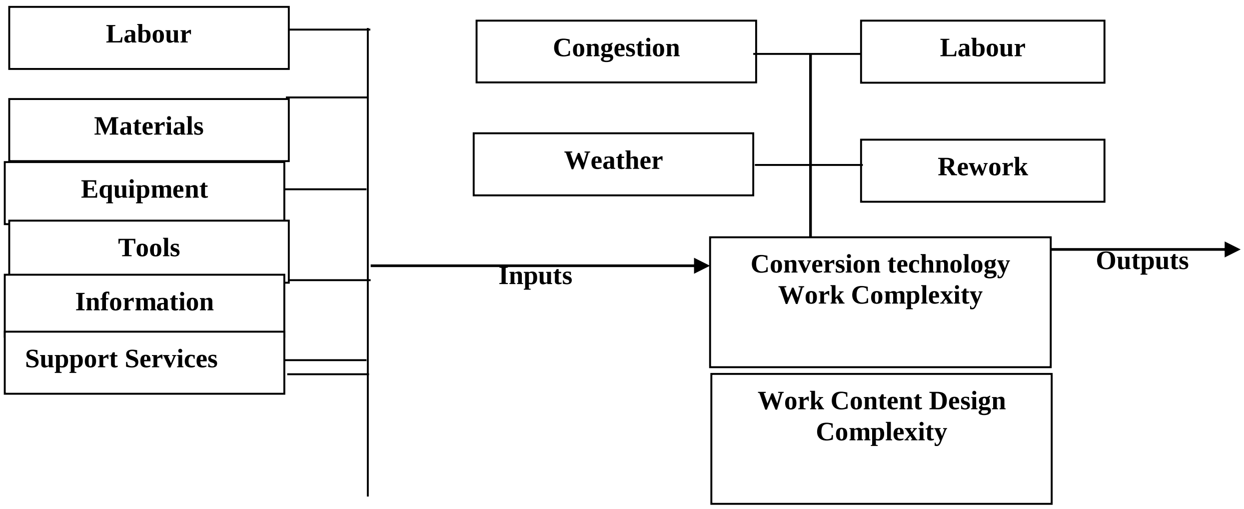


Figure 2: Factor – Resources Model

Variability in Labour Productivity

The variability in labour productivity provides a measure of level of capacity flexibility. It was calculated for each project by using the following equation:

$$\text{Productivity variation } (PV)j = \Sigma\sqrt{\frac{(\text{Urij - Baseline productivity})2}{n}}$$

Where urij = daily productivity (unit rate) for workday i on project; and n = number of work days on project J.

The coefficient of productivity variation (CPV) for each project is calculated as

$$\text{Coefficient of productivity variation (CPV)j} \quad \frac{\text{Pvj x 100}}{\text{baseline Productivity j}}$$

Where CPVj = coefficient of productivity variation for project j.

Baseline productivity was calculated by (Thomas 2000, Thomas and Zavrski 1999). The baseline productivity is calculated uniquely for each project by applying the following steps:

1. Determine the number of days that comprise 10% of the total work days observed.
2. Round this number to the next highest odd number; this number should not be less than five. This number n defines the size of (or number of work days in) the baseline subset.
3. Define the contents of the baseline subset as the n work days that have the highest daily production or output.
4. Calculate the sum of the work hours and daily output quantities for the n workdays in the baseline subset, and

5. Divide the sum of work hours in the baseline subset by the sum of the quantities in the baseline subset to determine the baseline productivity.

The baseline subset, from which the baseline productivity is calculated, contains days when there were little or no disruptions and the resources were readily available. Given the overlap between the elements of the factor-resources model and the learn principle, the baseline productivity is also a good estimate of productivity when learn principles are applied.

If there are adequate resources, no disruptions, and an appropriate conversion technology applied, then the input – output ratio or baseline productivity is affected only by the work content or decision complexity. Thus, the baseline productivity is the best performance a contractor can achieve for a particular design.

Table 1: Relationship between Factor–Resources Model and Learn Construction Principles

Factor Resources Model	Learn Construction Principles
Resources	• Improve flow Reliability
Disruptions	• Improve flow Reliability
Conversion Technology simplify operator/waste	• Eliminate
Work Content	

Project Waste Index

The project waste index (sometimes called the project management index) is calculated as project waste index (pwi).

$$= \frac{\text{Cumulative productivity - baseline productivity}}{\text{Expected baseline productivity}}$$

Coefficient of Quantity Variation

Another measure of variation, the variability in daily construction output for each project was calculated by using the following equation.

$$\text{Quantity Vairation (QVi)}$$
$$= \Sigma \sqrt{\frac{(\text{dqij - Average Daily Baseline Quantity})^2}{n}}$$

Where dqij = daily formwork

Quantity for workday I on project j, and n = number of workdays on project j.

The Quantity Variation (QV) for different projects cannot be compared directly because the average daily baseline quantities are different.

Therefore, the coefficient of quantity variation (CQV) for each project is calculated as:

$$\text{Coefficient of Quantity Variation (CQV)j}$$
$$\frac{= \text{QVj x 100}}{\text{Average Daily Baseline Quantity j}}$$

Where CQVj = coefficient of quantity variation for project j.

Synopsis

The implication of the above analysis is that the variability in daily labour productivity is more highly correlated to project performance than is the variability in daily construction output, especially when the worst performing projects are excluded.

Variability in productivity appears to be a good determinant of good and poorly performing projects. Thus, the goal of learn construction should be to improve performance by reducing variability in labour productivity.

Workflow and Learn Construction

In learn systems workflow refers to the movement of materials, information, and equipment through a system (Womack and Jones 1996). Smooth movement as in better workflow refers to avoiding the circumstances of continually changing from being in a state of movements to being stationary (Horman ad Kenley 1998). Erratic movements lead to waste that obstructs workflow and delays progress. Learn operators use techniques like rapid machinery changeovers, just – in – time population, pull scheduling and flexible capacity to improve flow and reduce waste since material, information, and equipment resources are components of workflow, smooth workflow means managing the availability of needed resources and components as they are modified and incorporated (value is added) into the completed structure or product. Through better workflow management, waste is eliminated and cost and schedule performance is improved. Ballard and Howell (1998) focused their attention on controlling planning reliability as the means to improve workflow reliability.

Arguably, their last planner technique has been the most developed use of learn thinking in construction to date. A set of rules is used to ensure the soundness of assignments before they are incorporated into the plan as follows.

1) Definition – that the assignment has been specified in adequate detail.
2) Soundness – that the requisite materials, information, and pre-requisite work is on hand.
3) Sequence – that the activities are aligned in the best order.
4) Size – that the assessment matches the capabilities of the crew, and
5) Learning – that the reason why tasks are incomplete are tracked.

Construction: By improving the soundness of planned assessments, the last planner is able to improve the smoothness of workflow. These rules, especially item 4, addresses the capacity of the crew and the work that is set for them, and hence in directly addresses labour flow.

Material: The material resource is an important component of workflow. There are many one-of –a kind items incorporated into construction project. Some are prefabricated and some are fabricated on site.

Materials are delivered to work locations throughout the project and their availability must be synchronized with a dynamic project schedule. Also, temporary stage to locations are identified and physical waste must be managed effectively (Thomas et al 1998).

Information: In construction, information needs can vary daily and come from multiple sources. Changed or late information can result in rework that requires substantial monies, labour hours, and time. Submittals, change orders, requests for information, jobsite correspondences and the construction contract ad sub contacts are information sources that the construction unique to construction. These are inevitable when building a one – of – a – kind facility described by in precise documents with a project team specifically organized for that project alone.

Equipment: In construction, equipment is mobile and is often shared by multiple crews. Equipment locations change as the project evolves. The duration that the equipment is assigned to a project is kept to a minimum to avoid excess expense. It is then dispatched to another project. Another problem unique to construction equipment is the frequency of maintenance problems, because construction equipment often works in a harsh environment. At times, equipment can be under-or-oversized because the proper size equipment is not available.

Labour Flow: Labour flow is distinct from work in that it involves the tracking and allocation of the labour resources to various tasks and work assignments. Also, covered in labour flow is the interaction of the crew with other crews and other work.

In construction, the number of work locations and manpower needs vary throughout the course of the project. Not all potential work locations are manned all of the time, and the number of craftsman needed varies, depending on the nature of the work being done at that time.

Previous research (Thomas et al 2002) suggests that variability in construction output at the crew level is inevitable, even on good performing projects. The key to good crew performance is to limit the variability in labour productivity by matching changes in workflow with flexible work assignment. This principle is practical in various ways on many jobs by dividing crew into work teams.

For example, when placing concrete, part of a try crew can be assigned to the placement while others can be assigned to erecting new formwork. Among other things, this suggests that labour is an important resource that needs to be more prominent in learn thinking.

Loss of Efficiency: The loss of labour efficiency is based on baseline productivity of 0.066wh/ft^2. On seventeen workdays, 909 work hours were charged, and of these 692 work hours were inefficiently used. The most significant course of loss of labour efficiency on project 9901 relates to the labour resources-specifically labour flow, i.e insufficient work to perform and overstaffing. Contractor had difficulty with the right make-up of labour resources needed for this project. The contractor's workforce management practices account for almost 80% of the inefficient work hours on this project.

Table 2: Loss of Learn Efficiency Calculations Project 9901

Workday	Category	Work hours	Equipment Quantities(ft^2)	Baseline	Should have been work hours	Insufficient work hours
4	Overstaffed	70	490.0	0.066	32	38
7	Interference	60	336.9	0.066	22	38
8	Workforce	50	112.3	0.066	7	43
9	management	48	490.0	0.066	32	16
10	Overstaffed	24	15.0	0.066	1	23
11	Insufficient work to	12	74.9	0.066	5	7
12	perform	50	74.9	0.066	5	45
	"					
	"					
14	Interference	50	89.9	0.066	6	44
15	Overstaff	77	579.9	0.066	38	39
16	Insufficient work to perform	28	15.0	0.066	1	27
17	"	60	362.9	0.066	24	36
18	"	60	25.2	0.066	2	58
19	"	60	11.5	0.066	1	59
21	Overstaff	77	361.2	0.066	24	46
24	Rain	50	228.0	0.066	15	35
25	Equipment	50	39.6	0.066	3	47
26	"	70	258.8	0.066	17	53
27	Rain	20	26.4	0.066	2	18
Total	**-**	**909**	**3,592.2**	**-**	**237**	**672**

Interference with other Crews

On workday 7, a rebar cage for the pier cap was being erected and the formwork crew could not plumb the formwork until the steel work was done. There were no alternate work assignments available. On workday 14, the formwork crew again waited for the steel reinforcement crew.

Insufficient Work to Perform

On these days, the formwork crew did very little work and much of the work actually done was incidental or low revenue producing work that is work that should be routinely accomplished concurrently with the normal production work. The work on these days included site clearing, removing through bolts, stripping formwork and installing gabions. Workdays 8,10,11,12,16,17,18 and 19 were affected.

Overstaffing: This issue is largely associated with the concrete placements.

Improving Performance by Managing Flows

The table below summarizes the inefficient work hours for the case study projects by cause. Of the 12,063 total work hours charged on the three projects, 4,610 work hours were inefficiently used. It shows the inefficient work hours attributed to labour flow and workflow. Weather is neither a labour flow nor workflow. Conversion technology relates to the method and is not considered as a flow. The inefficient work hours attributed to flow management (Labour flow and workflow). Are 3,816 of the total? This translates to a 51% loss of efficiency due to ineffective flow management alone. Thus there is strong evidence that applying reliability flow management principles will greatly improve labour performance.

Summary of Inefficient Work Hours by Cause

Table 3: Conversion Labour Flow Technology Workflow

Project weather	**Labour**	**Equipment**	**Rework**		
9901	519	100	-	53	-
9904	915	498	831	51	514
9906	796	-	157	176	-
Total	**2,230**	**598**	**988**	**280**	**514**

Projects 9901, 9904 and 9906 had a total of 3,836 work hours which amount to $96,400 (at $25/h). Each project had its own work hour with a 76 crew work days (at 50 work hours per day).

The table also shows that labour accounts for 58% of the total flow losses, and workflow accounts for the remaining 42% (workflow includes equipment and information). Yet, labour as a flow has received little flow in learn thinking. It seems that by not including labour as a component of flow, the application of learn principles ignores a potentially large opportunity for cost and schedule improvement. This observation supports the work of Horman on developing flexible capacity strategies for learn construction (Horman and Kenley 1998, Horman 2000).

The Roles of a Project Manger

Systems management, programme management and product management are terms often used to describe the integrated nature of managing projects. The project manager acts as a focal point for the concentration of attention on the major problems of the project. He has the proper idea of integrating relative matters of cost, time, technology and the total product compatibility. This project or programme approach has been found very useful throughout the industrialized as well as the developing economic like Nigeria, Ghana and Kenya, and the process of project formulation and their management.

The project manager is responsible for organized all activities and resources of the project in such a way as to achieve the project objective. He is also required to control and co-ordinate the overall activities of the project. Thus, the project manager takes a project from the beginning and works it through completion. And once a particular project is completed, the special organization association with it is also terminated. Thus, any committee set for a particular project is also dissolved on completion of that particular project.

Project management, however, is far from being a cure-all for the embarrassments, expenses and delays that plague even the best-managed companies.

First, project management requires temporary shifts of responsibilities and reporting relationship that may disturb the smooth functioning of the regular organization. Second, it requires unusually disciplined executive effort. Figure 1 and 2 below show some new and powerful management or complex projects.

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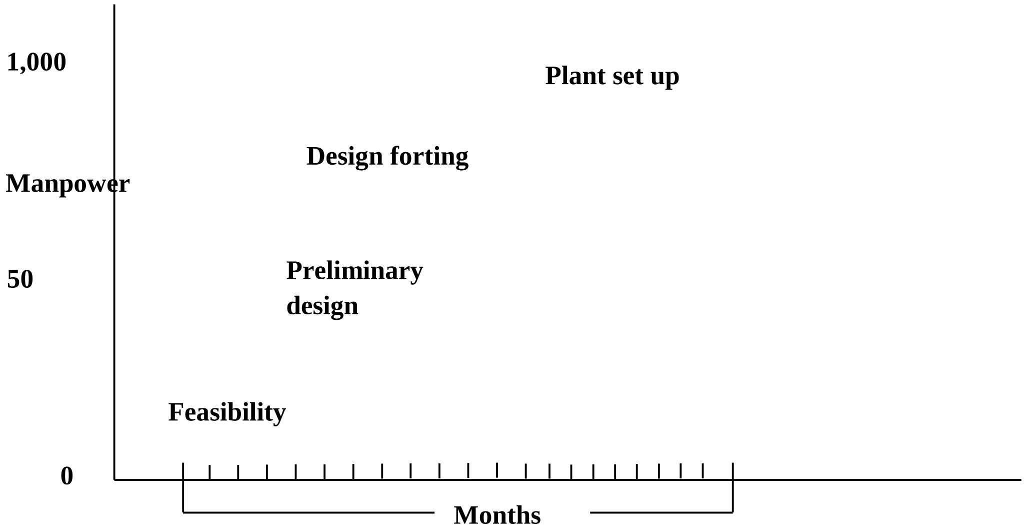

Figure 2: Manpower Commitment to New Production Introduction Project

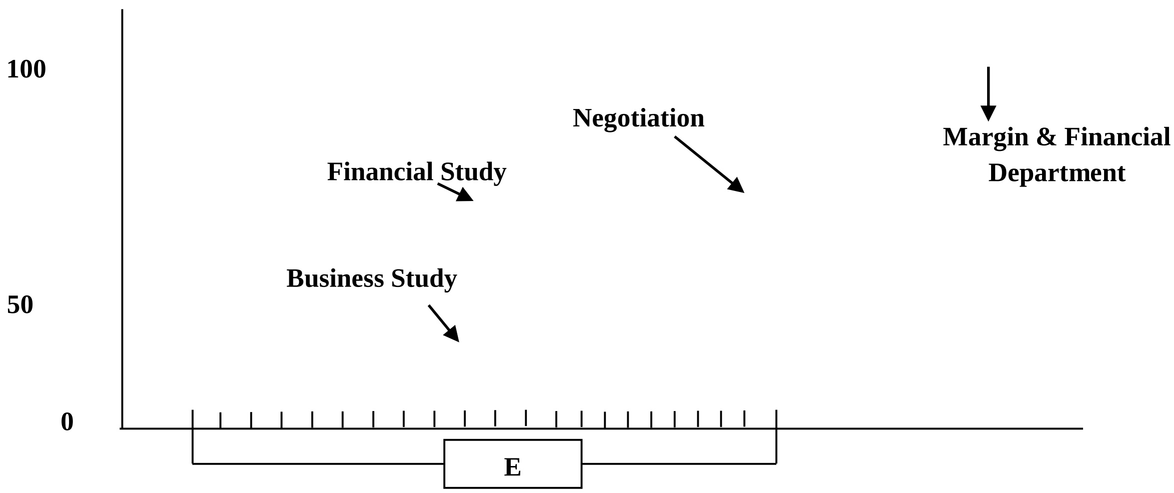

Figure 3: Manpower Commitment Merger Project

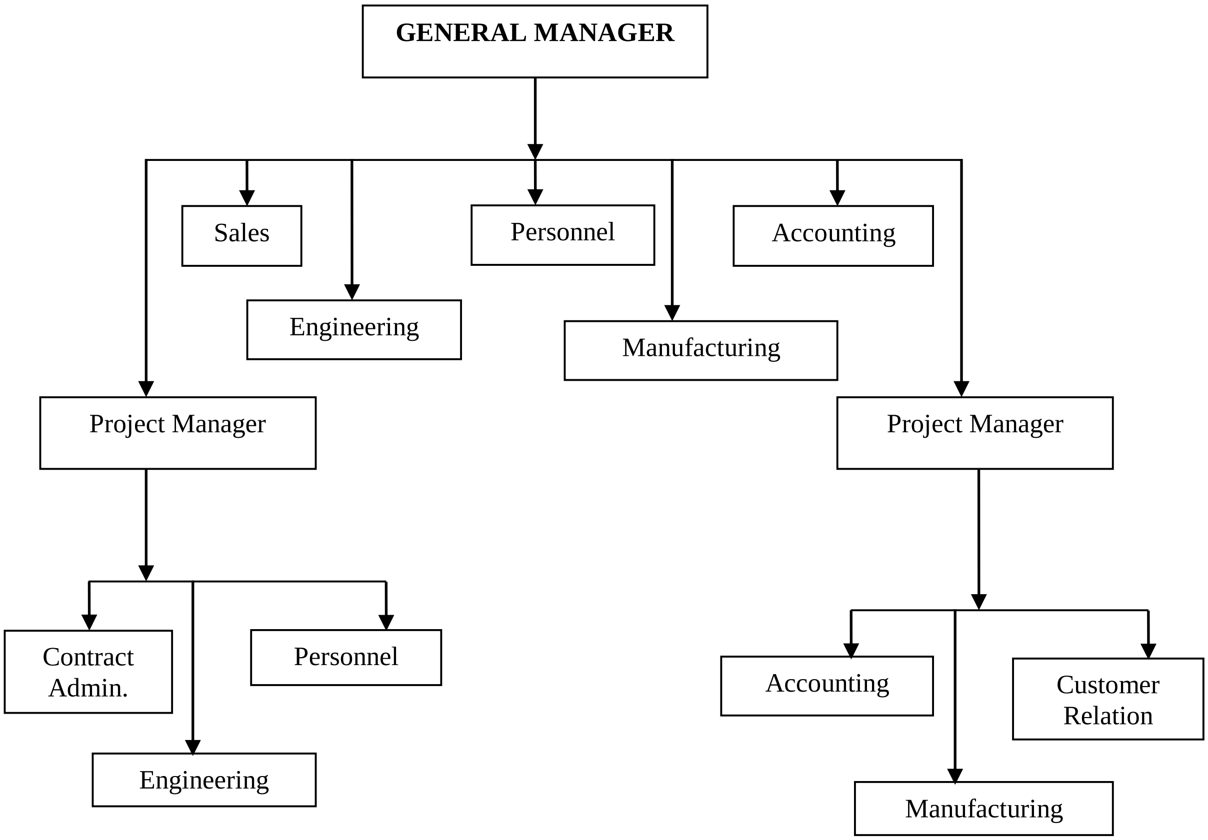

Figure 4: Typical Project Organization in the Aerospace and Construction Industries

The knowledge of learn construction principles should be well understood by project managers in such a way as to utilize resources effectively, promote the eliminating of waste and non-value adding activities in the process, to engineering and design.

In the construction industries and aerospace complete responsibility for the task, as well as all the resources needed for its accomplishment, is usually assigned to one project manager. Outside the aerospace and construction industries, however, the project manager is usually not assigned complete responsibility for resources. He may have project organization consisting of a handful of men temporary assignment from the regular functional organization. The function managers, managers, however, retain their direct line authority, monitor their staff's construction to the project and continue to make all major personal decisions.

METHODOLOGY

Research Design

This chapter is a description of procedures adopted to collect data about the project topic. The procedures adopted are therefore used to study how lean Construction principles and techniques can be applied in the construction industry in order to eliminate waste and enhance productivity as well as the role of the project manager in adopting the lean principle.

Data Collection Methods

The data collection method of any research work depends on the objectives of the study and the data requirements. In this research exercise, the methods of data collection are as follows:

Primary Data

This is firsthand information collected by means of personnel interview with Construction industry principal actors and professionals both in the public and private sectors. The primary data collection method was adopted by extraction of questionnaire, direct interviews, field survey and personal observation.

Secondary Data

This was based on review of related literatures, book, journals, seminar papers, reports and other published and unpublished materials that were considered relevant in the research exercise.

CONCLUSION AND RECOMMENDATION

The focus of this research has been on Lean Construction and what Construction industries will benefit from having knowledge of the Lean Construction Fundamentals.

Lean Construction supports the development of team work and a willingness to shift burdens along supply chains. Partnering relationships coupled with Lean thinking make rapid implementation possible.

The Problem of matching labor to available work offer a good example of the difference between contemporary view of the workplace and Lean. "Matching Labor to work" means having the resources on hand for the crew to work steadily and without interruptions.

If project managers in the construction industry will understand and apply Lean Construction Techniques in the construction works, waste will be reduced and maximum output of construction works will be achieved with lesser time. The principle of Lean is practical and can be applied in any production process to achieve the result with lesser resources and time.

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