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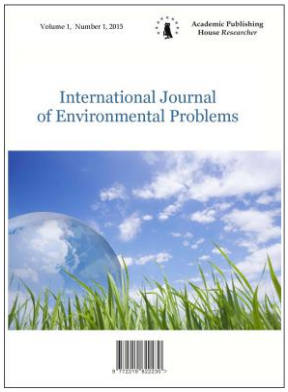

Assessment on the Barriers to Application of Lean Principles at the Construction Stage in Bauchi Metropolis

M.M. Mukaddas [a, *], A. Mohammad [b], F.A. Mohammad [a]

[a] Department of Quantity Surveying, School of Environmental Technology, Abubakar Tatari Ali Polytechnic Bauchi, Nigeria
[b] Works Department, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria

Abstract

Material waste has been a great nuisance in the construction industry. It is the major cause of the high cost, low value and poor service delivery in the construction industry. The purpose of this study is to provide data that will increase knowledge on waste minimization in construction sites by identifying sources and causes of avoidable waste on construction sites and valuation of level of knowledge of the lean concepts among construction specialists and recognizing obstacles to effective application of the lean concept in construction. Data for the study were obtained through site visitations, interviews and the administration of 1000 questionnaires. Respondents included all the major professionals in the construction industry. Ratios and Simple percentages were used to analyze the data. Data from the analyses indicated about 10 % to 33 % of total construction materials are wasted on site. Results also revealed that method of operation, storage and handling of construction materials, procurement methods, record keeping and design were the major sources of waste on construction sites. It also revealed the presence of some degree in knowledge of lean construction among the construction experts.

Keywords: construction, waste, lean construction, manufacturing, operation.

1. Introduction

The manufacturing industry has experienced tremendous improvements and significant performance which can be equated with increasing productivity. The most significant feature in this accomplishment was the implementation of the novel philosophy of production, known as "Lean Production" By the removal of myriad types of waste; this approach has provided a continuous improvement in the production process (Ward, Sobek II, 2014).

Despite the fact that manufacturing had attained enormous results, the construction industry still encounters stern problems resulting from massive amounts of waste (Womack, Jones, 2010) hence, the need for lean construction to help curb the wastage issue. Past research into the causes of waste in construction projects indicate that waste can arise at any stage of the construction process from inception, right through the design, construction and operation of the built facility (OJEBA, L. G. T. P. O.).

Waste in the construction industry has been the subject of several research projects around the world in recent years (Pacheco-Torgal, Labrincha, 2013; Ashworth, Hogg, 2014; Ball, 2014;

* Corresponding author
E-mail addresses: mariamukaddasm@yahoo.com (M.M. Mukaddas)

Bhasin, 2015; Gandaa, 2015; Gandaa, 2015). According to Ball, M. (2014), it is commonly acknowledged that a very high level of waste exists in construction. Since construction has a major and direct influence on many other industries by means of both purchasing inputs and providing the products to all other industries, eliminating or reducing waste in the construction industry could yield great cost savings to the society.

According to Agyekum, (2012), waste can be defined as "any inefficiency that results in the use of equipment, materials, labour or capital in larger quantities than those considered as necessary in the construction of a building". Waste can be classified as *unavoidable waste* (or natural waste), in which the investment necessary for its reduction is higher than the economy produced, and *avoidable waste,* in which the cost of waste is higher than the cost to prevent it.

Lean construction considers construction materials wastes as potential wastes that hinder flow of value to the client and should be eliminated (Gregory, 2010). The creation of this waste can be prevented by applying lean construction principles. The question now arises as to whether professionals in the building industry in Nigeria are aware of the amount of materials waste generated on site. What measures have they put in place to deal with the situation?

The study covered only the construction stage of building projects with the assumption that lean design has already been considered at the design stage. Construction stage refers particularly to the building or construction of sub-structures, super-structures and architectural elements such as finishes. Surveys carried out at these phases enabled on-site observations to be conducted simultaneously. The materials considered were timber, cement/mortar, concrete and blocks. The research focused on the flow activities of these materials (storage and handling). Surveys in the forms of questionnaires and personal interviews were conducted with the proponents who were undertaking referenced projects. Proponents mentioned refer precisely to the site managerial staffs concerned such as project managers, quantity surveyors and architects. The study focused on construction sites in and around Bauchi metropolis due to site accessibility and availability of contacts. These sites were mainly made up of construction of lecture theatres, offices, student hostels and residential buildings.

2. Relevance

Agyekum (2012) describes waste as "any inefficiency that results in the use of equipment, materials, labour or capital in larger quantities than those considered as necessary in the construction of a building". Waste can be classified as *unavoidable waste* (or natural waste), in which the investment necessary for its reduction is higher than the economy produced, and *avoidable waste,* in which the cost of waste is higher than the cost to prevent it (Bhasin, 2015). The percentage of unavoidable waste depends on the technological development level of the company (Bhasin, 2015). Ramos (2010) stated that waste can also be categorized according to its source; namely the stage in which the root causes of waste occurs. Waste may result from the processes preceding construction, such as materials manufacturing, design, materials supply, and planning, as well as the construction stage (Harris, 2013) classified the main waste causes in construction into: Design; Procurement; Materials Handling; Operation; Residual.

However, for the sake of this study, only materials wasted at the construction stage of projects would be considered. This is due to two main reasons:

1. Materials account for the largest input into construction activities in the range of 50-60 % of the total cost of a project (Ramos, 2010) and because

2. The raw materials from which construction inputs are derived come from non-renewable resources. Hence, rarely would these materials be replaced once they are wasted (Udeaja et al., 2013).

3. Materials and Methods

In this study, data was collected through interviews using structured questionnaire on a site visit. The questionnaire was self-administered to respondent and information gathered at the spot to collect detailed information about respondents‟ experiences and impressions about materials wastage and lean construction. It was also used to collect preliminary information to help in structuring the questionnaires. The questionnaire survey was also adapted to get feedback on opinions of respondents‟ about wastage of building materials and the implementation of lean

principles in the Nigerian construction industry. The site visits also involved observations where the researcher sought to find out how materials are stored and handled and also provide a compendium on high waste generating building materials are used in the construction industry. The researcher spent 4 months on building construction sites and observed the flow of activities of materials (handling and storage). Only handling and storage was considered on the questionnaire survey.

Sources of Data

The study depended on both primary and secondary data. Primary data was developed from first-hand data collected through the use of questionnaires, interviews and site visits (observation). The secondary source of data was obtained using relevant books, journals, magazines and research papers.

Questionnaire *Design*

The questionnaire consisted of 6 major sets of closed-ended questions designed to obtain data on the sources and causes of materials waste and waste minimization measures, the questionnaire further sought to obtain information on the level of knowledge of construction professionals on the concept and benefits of lean construction and barriers to the implementation of lean construction in the Nigerian building industry. Interviews were also used to obtain more specific information about material waste and lean construction.

The question was constructed using the Linkert scale. The respondents were asked to rank on a scale of 1-5 factors that cause materials waste on construction sites where 1= „Highly unimportant", 2= „Unimportant", 3= „Neutral", 4= „Important" and 5= „Highly important".

For each waste minimization measure, the respondents were asked to score the level of contribution to waste minimization on the Likert scale of 1 to 5 where 1= „very low", 2= „low", 3= "Medium", 4= „High" and 5= „Very high".

The respondents were further asked to score each measure according to the level of practice in their organization on a scale of 1 to 5 where 1= „Not practiced at all", 2= „Not practiced", 3= „Practiced", 4= „Frequently practiced" and 5= „Most frequently practiced".

Concerning the principles of lean construction, the respondents were asked to indicate their level of agreement to the application of the principles to project delivery in the construction industry on a five- point Likert scale (from 1= „highly disagree" to 5 = „highly agree"). For the achievability of customer values, respondents will be asked to rank from 1 = „highly unachievable" to 5= „highly achievable".

For the benefits of lean construction, the respondents were asked to rank from 1 = „highly unbeneficial" to 5 „highly beneficial" and for measures to bridge the knowledge gap, respondents were asked to rank from 1 „highly unimportant" to 5 „highly important".

On the issues of barriers to the implementation of lean construction, the respondents were asked to score the severity of the potential barriers out of the forty which were pre-tested to the implementation of lean construction on the Likert scale of 1-5 where 1= „Not very severe" and 5= „Very severe". The 17 measures to overcome potential barriers to implementation of LC were also scored on a scale of 1-5, where 1= „Highly Unimportant", 2= „Unimportant", 3= „Neutral", 4= „Important" and 5= „highly important.

The target population for the data collection using the questionnaires consisted of consultancy firms (architectural and quantity surveying) and construction organizations. Building construction organizations operating within Bauchi metropolis registered with the Ministry of Water Resource, Works and Housing (MWRWH): based on the nature of work the organizations engage in – building, civil engineering construction, electrical and plumbing works as classified respectively.

4. Discussion

The report of the findings the survey after the questionnaire survey was carried out is presented here. Statistical analysis of the responses using ratios and percentages was carried out. Describes the characteristics of the respondents in terms of profession (Figure 1); level of education (Figure 2); experience (Figure 3).

Unnecessary delays in materials delivery, inefficient use of quality standards, long implementation period, waste accepted as inevitable, inconsistency in government policies, high

dependency of design specifications on in-situ components and materials, extensive use of subcontractors, lack of long term commitment to change and innovation, lack of long term relationship with suppliers, delays in decision making and materials scarcity(Figure 4); fragmented nature of the construction industry, lack of interest from clients, poorly defined individual responsibilities and less involvement of contractors and specialists in design process(Figure 5); poor project definition, lack of equipment, lack of buildable designs, incomplete designs and lack of standardization, lack of agreed implementation methodology and unsuitable organizational structures (Figures 6, 7 and 8); Figures 9 and 10 show the level of material wastage on site and measures that aid in waste minimization respectively. Figures 11, 12 and 13, 15-19 depicts understanding, level of adoption and hindrance on applicability of lean principles, while Figure 14 shows the level of achievability of consumer values in company operations.

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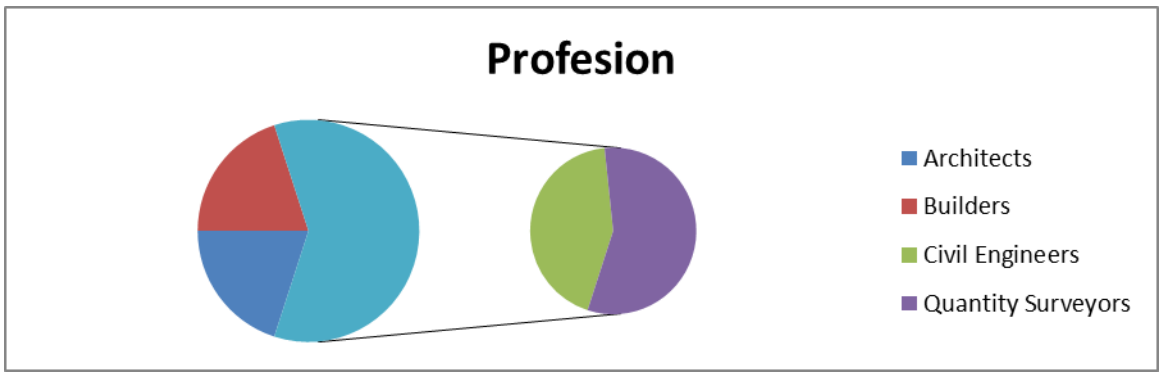

Fig. 1. Characteristics of the sample (% Profession)

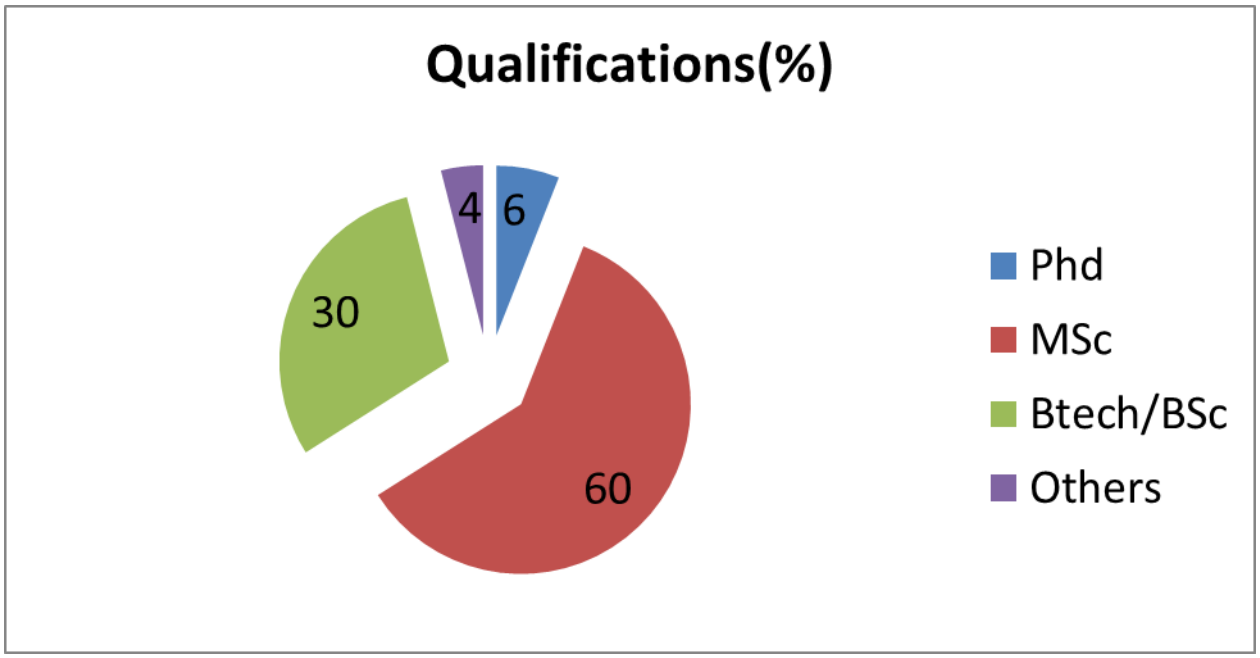

Fig 2. Characteristics of the sample (%)

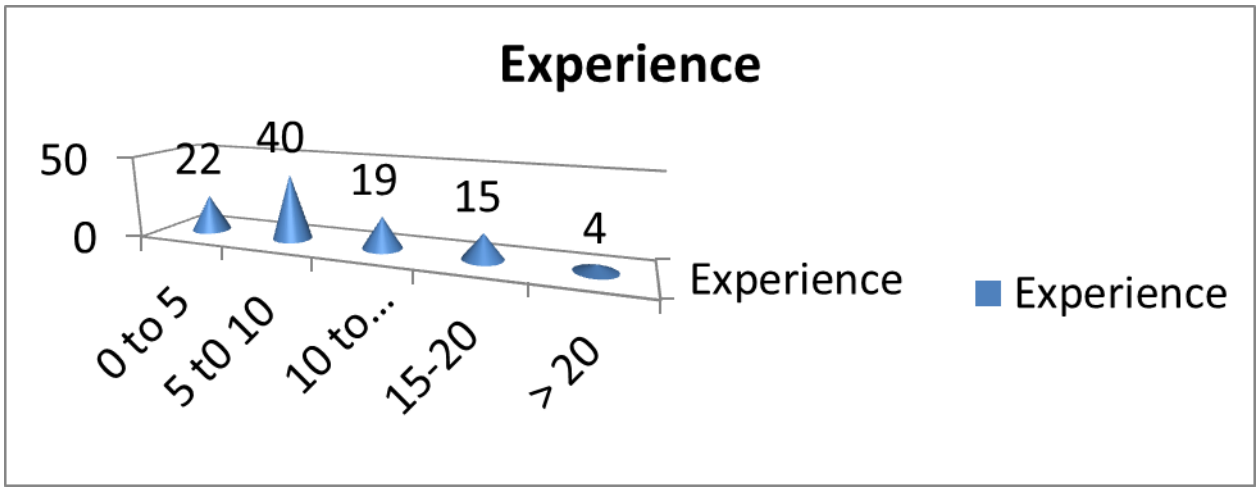

Fig. 3. Characteristics of the Sample (experience, %)

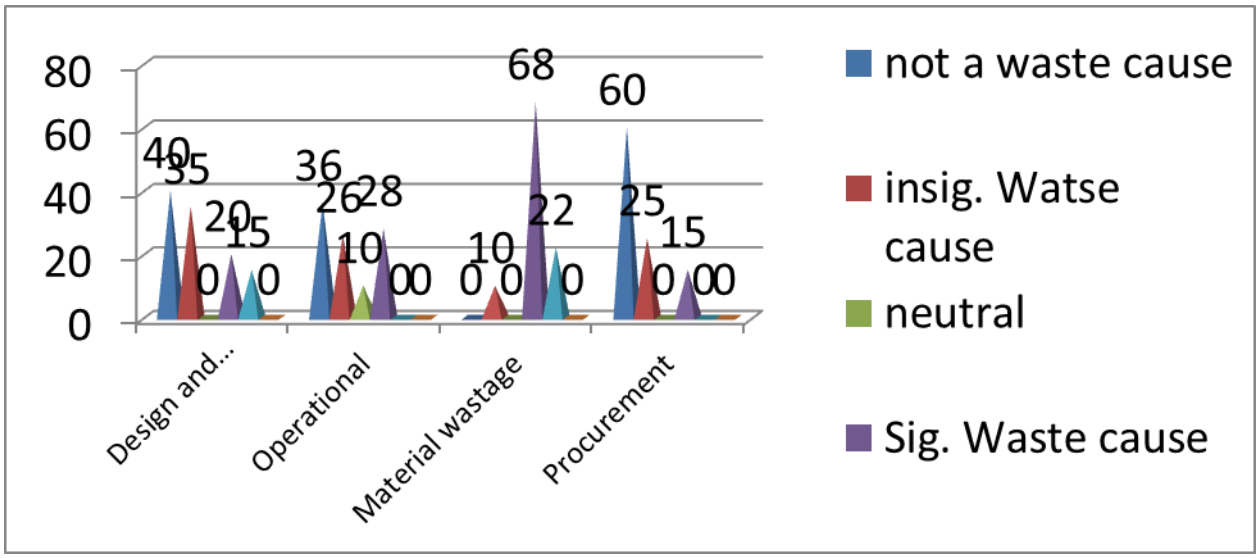

Fig. 4. Possible Sources of Construction Waste

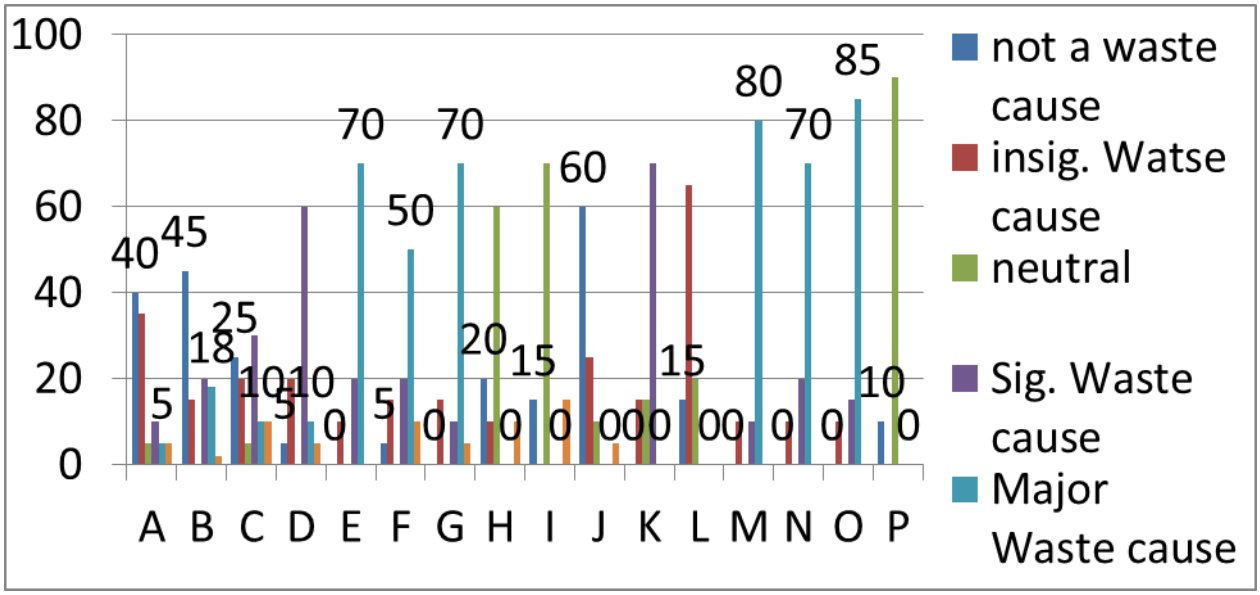

Fig 5. Possible sources of construction waste (design and documentation)

Key

A	Lack of attention paid to dimensional consideration of products
B	Variations in the design during construction
C	Designer inexperience in method and sequence of construction
D	Lack of attention paid to standard sizes available in the market
E	Designers unfamiliarity with alternative products
F	Complexity of detailing in drawings
G	Lack of information in drawing
H	Poor/wrong specifications
I	Incomplete contract documents at commencement of project
J	Selection of low quality products
K	Last minute client requirement
L	Poor communication leading to mistakes and errors
M	Overlapping of design and construction

N Lack of knowledge about construction techniques during design
P Poor site layout

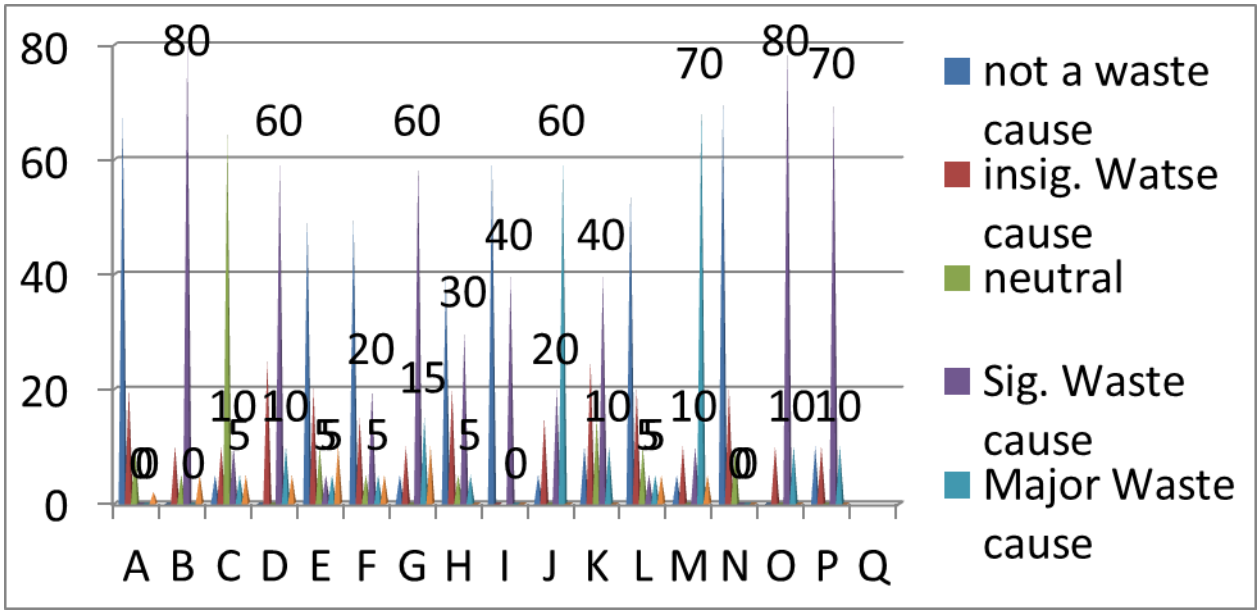

Fig. 6. Possible Sources and sources of Construction Waste (Operational, %)

KEY
- A ERRORS BY TRADES MEN OR OPERATIVES
- B ACCIDENTS DUE TO NEGLIGENCE
- C DAMAGE TO WORK DONE CAUSED BY SUBSEQUENT TRADES
- D USE OF INCORRECT MATERIALS THUS REQUIRING REPLACEMENT
- E REQUIRED QUALITY UNCLEAR DUE TO IMPROPER PLANNING
- F DELAYS IN PASSING OF INFORMATION TO THE CONTRACTOR ON TYPES AND SIZES OF PRODUCTS TO BE USED
- G EQUIPMENT MALFUNCTIONING
- H INCLEMENT WEATHER
- I INAPPROPRIATE PLACEMENT OF THE MATERIAL
- J POOR INTERACTION BETWEEN VARIOUS SPECIALISTS
- K CHOICE OF WRONG CONSTRUCTION METHOD
- L UNFRIENDLY ATTITUDES OF PROJECT TEAM AND LABORS
- M EFFECTS OF POLITICAL AND SOCIAL CONDITIONS
- N DIFFICULTIES IN OBTAINING WORK PERMITS
- O FREQUENT BREAKDOWN OF EQUIPMENT
- P POOR TECHNOLOGY OF EQUIPMENT
- Q SHORTAGE OF TOOLS AND EQUIPMENT REQUIRED

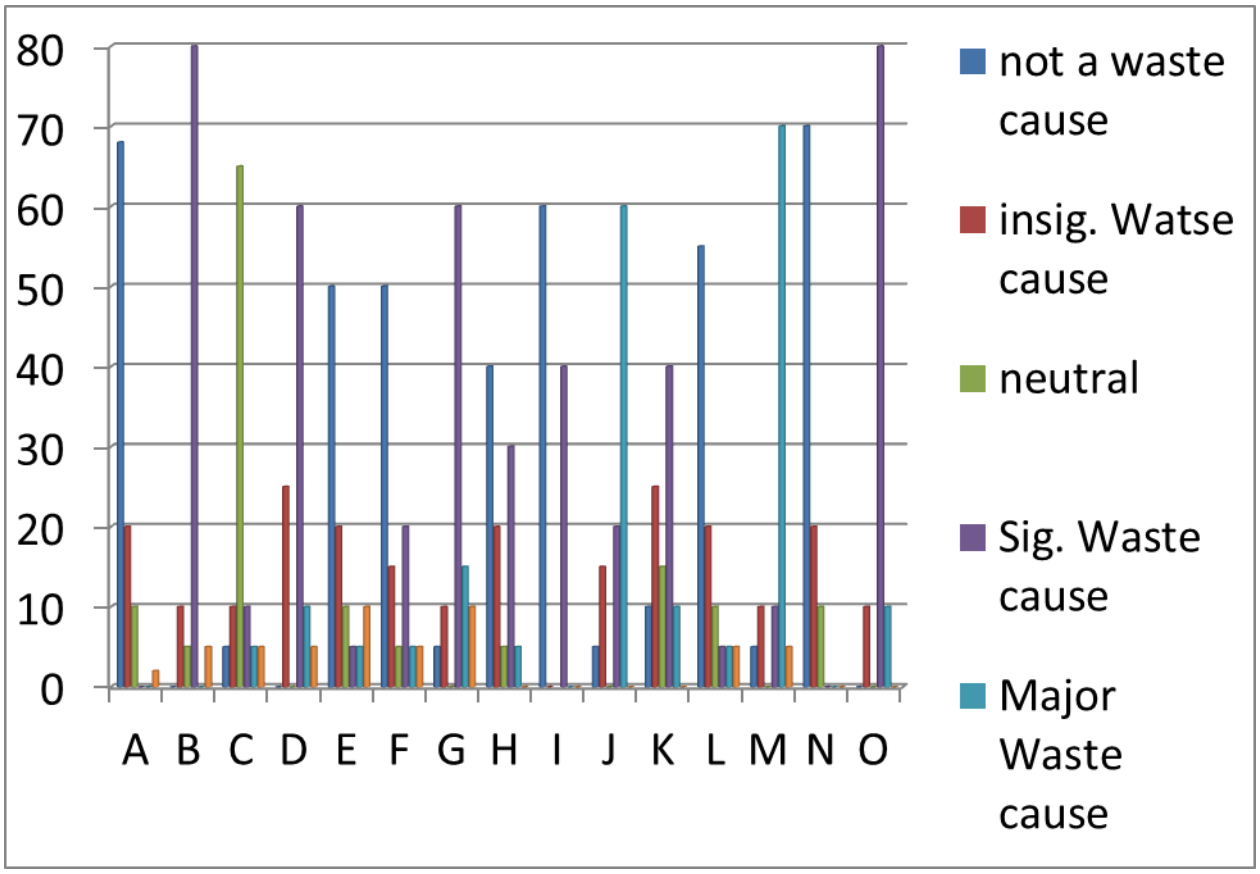

Fig. 7. Possible Source and sources of Construction Waste (Material Wastage)

KEY

- A OVERLOADING OF TRANSPORT EQUIPMENT
- B USE OF WRONG METHOD OF TRANSPORT
- C POOR METHOD OF STORAGE ON SITE
- D POOR HANDLING. E USE OF WHATEVER MATERIAL CLOSE TO WORKING PLACE
- F THEFT. G DAMAGE TO MATERIAL ON SITE
- H WASTE RESULTING FROM CUTTING UNECONOMICAL SHAPES
- I UNNECESSARY INVENTORIES ON SITE LEADING TO WASTE
- J OVERPRODUCTION/PRODUCTION OF A QUANTITY GREATER REQUIRED OR EARLIER THAN NECESSARY
- K MANUFACTURING DEFECTS
- L LACK OF ONSITE MATERIALS CONTROL
- M USING EXCESSIVE QUANTITIES OF MATERIALS THAN REQUIRED
- N INSUFFICIENT INSTRUCTIONS ABOUT HANDLING

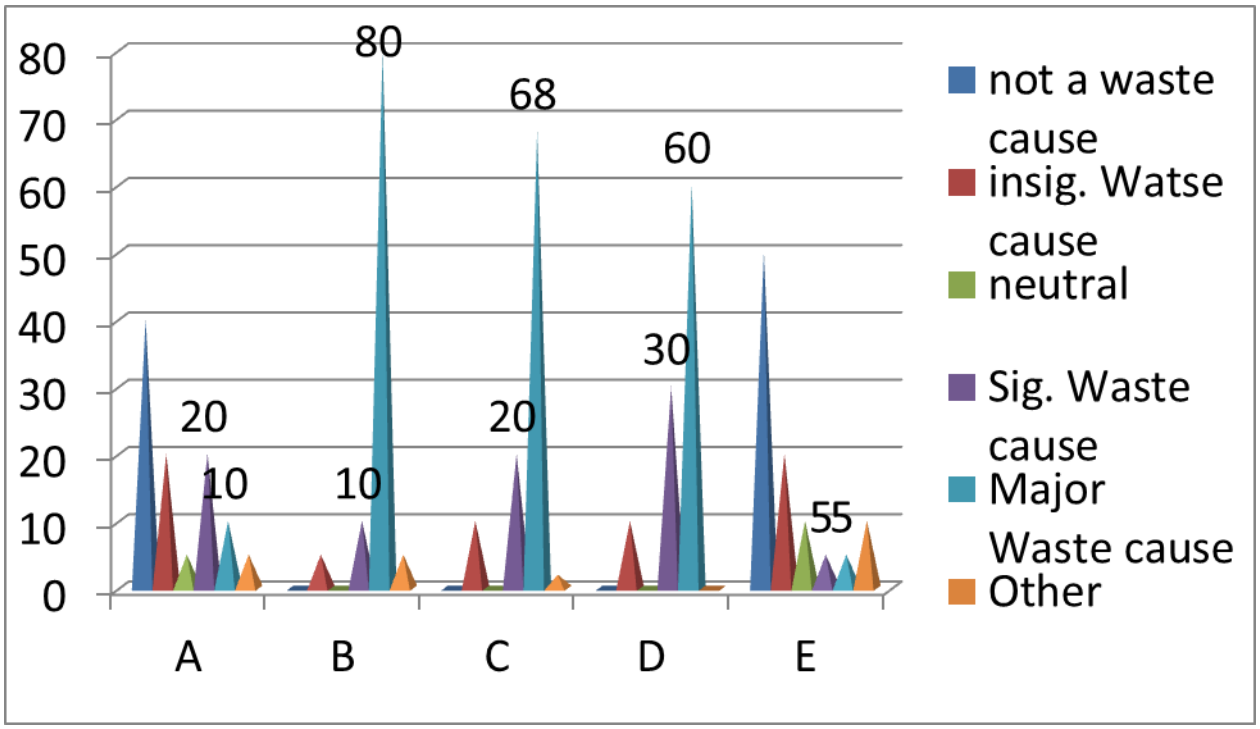

Fig. 8. Possible sources construction waste (Procurement) (%)

KEY

- A ORDERING ERRORS (EXAMPLE, ORDERING SIGNIFICANTLY MORE OR LESS)
- B PURCHASED PRODUCTS THAT DO NOT COMPLY WITH SPECIFICATION
- C UNSUITABILITY OF MATERIALS SUPPLIED TO SITE
- D SUBSTITUTION OF A MATERIALS BY A MORE EXPENSIVE ONE(WITH AN UNNECESSARY BETTER PERFORMANCE)
- E CHANGES IN MATERIAL PRICES

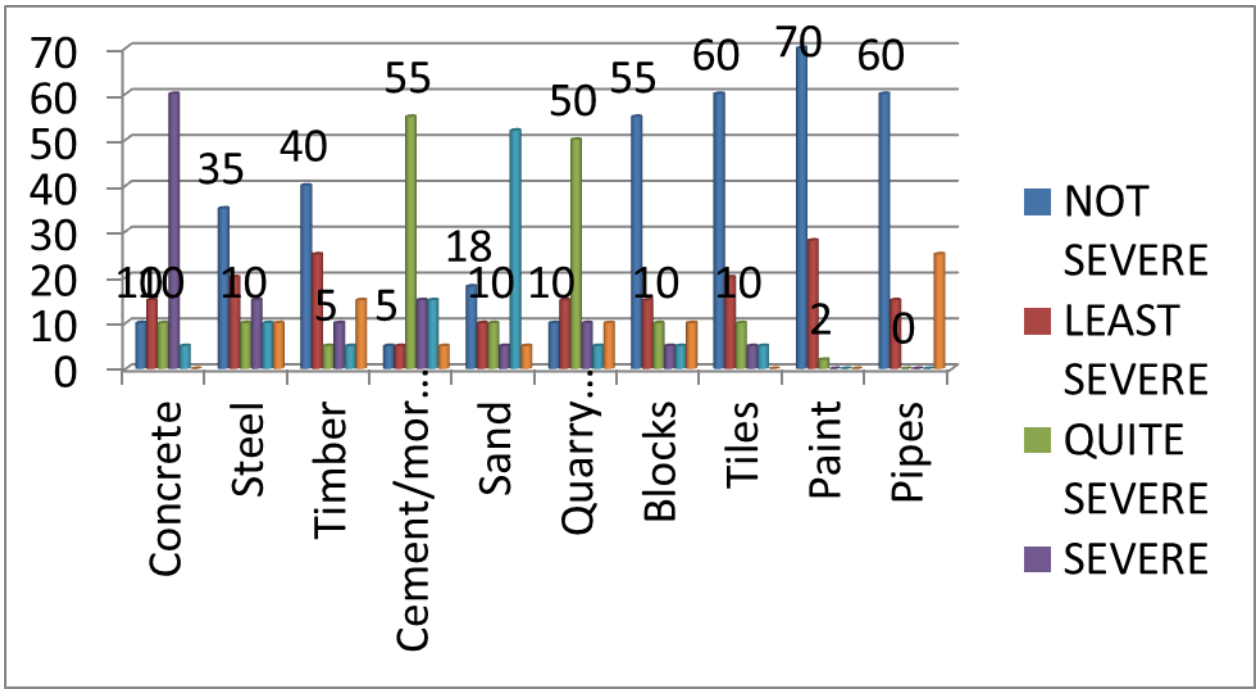

Fig. 9. Material wastage on site (%)

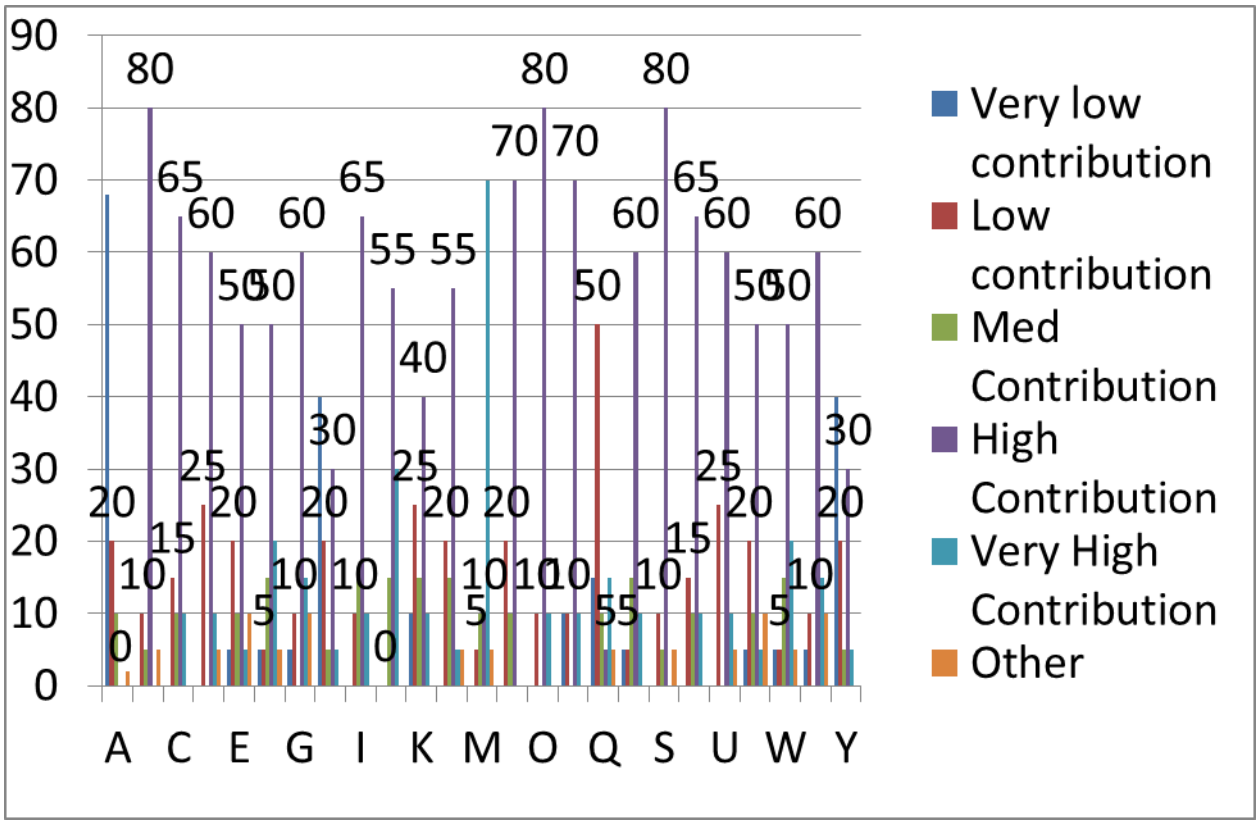

Fig. 10. Measures that contribute to minimization of waste (%)

KEY

- A RECYCLING OF SOME WASTE MATERIALS ON SITE
- B GOOD CONSTRUCTION MANAGEMENT PRACTICES
- C TRAINING OF CONSTRUCTION PERSONNEL

D GOOD COORDINATION BETWEEN STORE AND CONSTRUCTION PERSONNEL TO AVOID OVER-ORDERING

- E USE OF MORE EFFICIENT CONSTRUCTION EQUIPMENT
- F VIGILANCE OF SUPERVISORS
- G PROPER STORAGE OF MATERIALS ON SITE
- H JUST IN TIME OPERATIONS
- I EARLY AND PROMPT SCHEDULING OF DELIVERIES
- J ADHERENCE TO STANDARDIZED DIMENSIONS
- K CHANGE OF ATTITUDE OF WORKERS TOWARDS THE HANDLING OF MATERIALS
- L REGULAR EDUCATION AND TRAINING OF PERSONNEL ON HOW TO HANDLE
- M CHECKING MATERIALS SUPPLIED FOR RIGHT QUALITIES AND VOLUMES
- N EMPLOYMENT OF SKILLED WORKMEN
- O ACCURATE AND GOOD SPECIFICATIONS OF MATERIALS TO AVOID WRONG ORDERING
- P ENCOURAGE RE-USE OF WASTE MATERIALS IN PROJECTS
- Q CAREFUL HANDLING OF TOOLS AND EQUIPMENT ON SITE
- R WEEKLY PROGRAMMING OF WORKS
- S MIXING, TRANSPORTING AND PLACING CONCRETE AT THE APPROPRIATE TIME
- T WASTE MANAGEMENT OFFICER OR PERSONNEL EMPLOYED TO HANDLE WASTE ISSUES
- U ADOPTION OF PROPER SITE MANAGEMENT TECHNIQUES

- V ACCESS TO LATEST INFORMATION ABOUT TYPES OF MATERIALS ON THE MARKET
- W MINIMIZING DESIGN CHANGES
- X PURCHASING RAW MATERIALS THAT ARE JUST SUFFICIENT
- Y USING MATERIALS BEFORE EXPIRY DATES

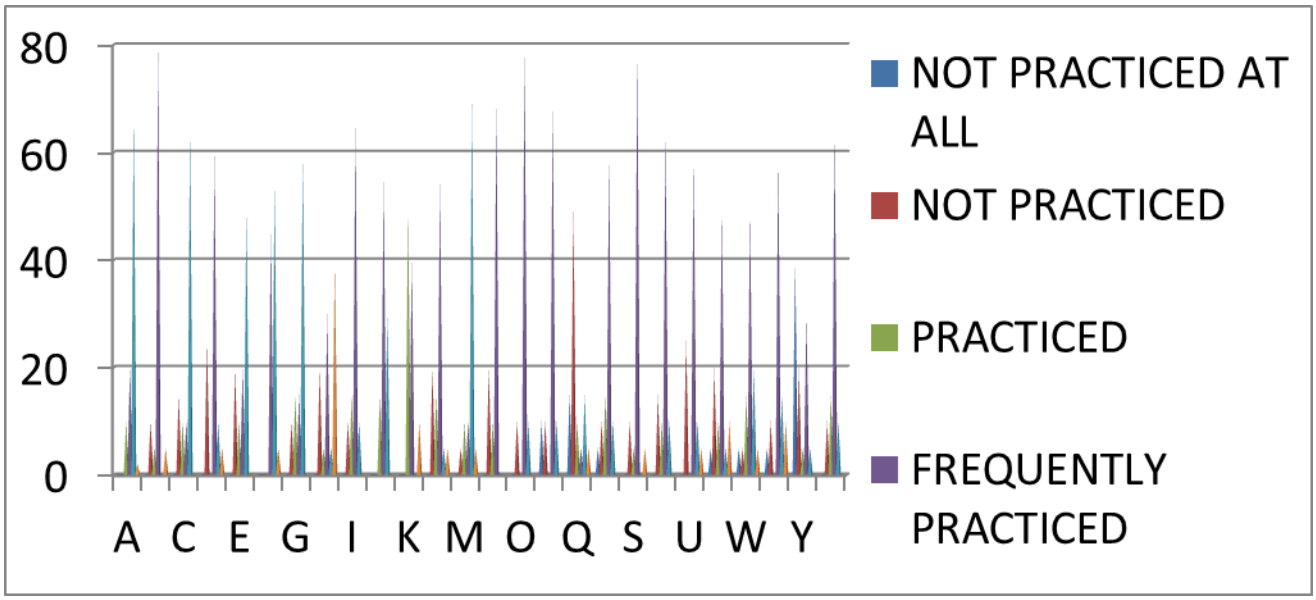

Fig 11. Frequency of use of minimization of waste measures

KEY

- A RECYCLING OF SOME WASTE MATERIALS ON SITE
- B GOOD CONSTRUCTION MANAGEMENT PRACTICES
- C TRAINING OF CONSTRUCTION PERSONNEL

D GOOD COORDINATION BETWEEN STORE AND CONSTRUCTION PERSONNEL TO AVOID OVER-ORDERING

- E USE OF MORE EFFICIENT CONSTRUCTION EQUIPMENT
- F VIGILANCE OF SUPERVISORS
- G PROPER STORAGE OF MATERIALS ON SITE
- H JUST IN TIME OPERATIONS
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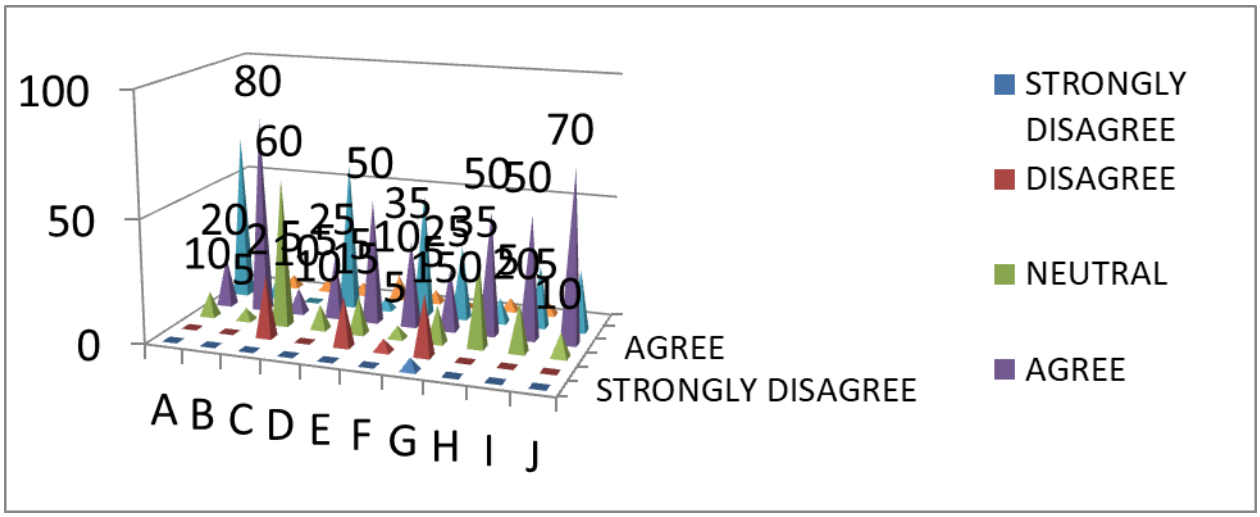

Fig. 12. Application of Lean Principles in Projects

KEY
• A DELIVERING WHAT THE CLIENT WANTS
• B ESTABLISHING CONTINUOUS IMPROVEMENT: THUS, REDUCTION OF COSTS, INCREASE IN QUALITY AND PRODUCTIVITY
• C DOING THE RIGHT THINGS AT THE FIRST TIME: THUS ACHIEVE ZERO DEFECTS, REVEALING AND SOLVING PROBLEMS AT THE SOURCE
• D AVOIDING DEFECTS IN THE WORKS DONE THAT CAN RESULT IN FOR EXAMPLE, WASTE, UNNECESSARY REWORK, LOSS OF CUSTOMERS AND CORPORATE REPUTATION
• E INVOLVING THE WHOLE PROJECT TEAM THROUGH THE DESIGN TO CONSTRUCTION
• F CONSTANTLY SEEKING BETTER WAYS TO DO THINGS
• G INCREASING OUTPUT VALUE THROUGH SYSTEMATIC CONSIDERATION OF CUSTOMER REQUIREMENTS
• H INCREASING OUTPUT FLEXIBILITY: THUS THE PRODUCTION OF DIFFERENT MIXES AND/ OR GREATER DIVERSITY OF PRODUCTS, WITHOUT COMPROMISING EFFICIENCY
• I WASTE MINIMIZATION: THUS, ELIMINATING ALL NON-VALUE ADDING ACTIVITIES AND MAXIMIZING THE USE OF ALL RESOURCES
• J BUILDING AND MAINTAINING LONG-TERM RELATIONSHIPS WITH SUPPLIERS

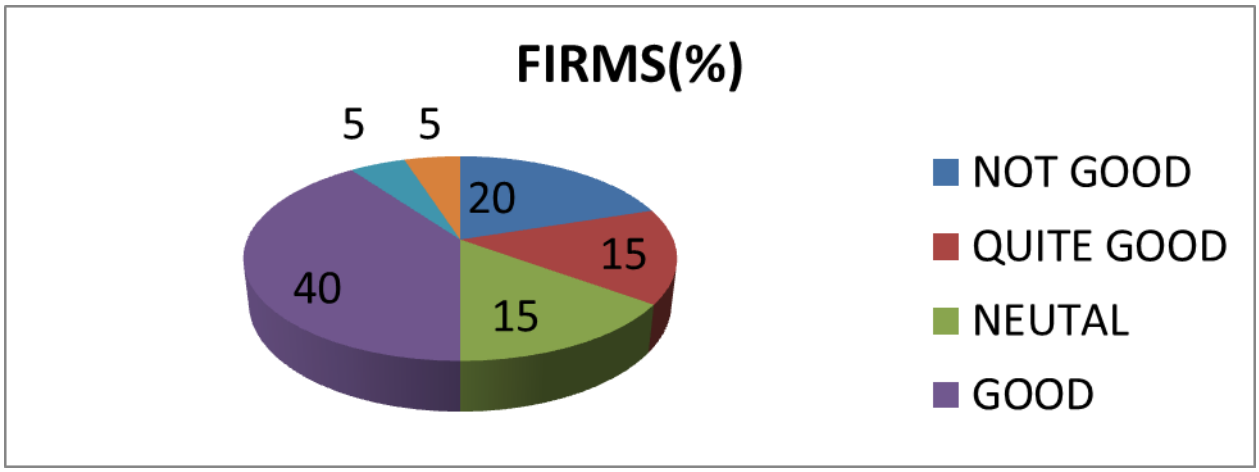

Fig 13. Transferability of Lean Principles to Construction

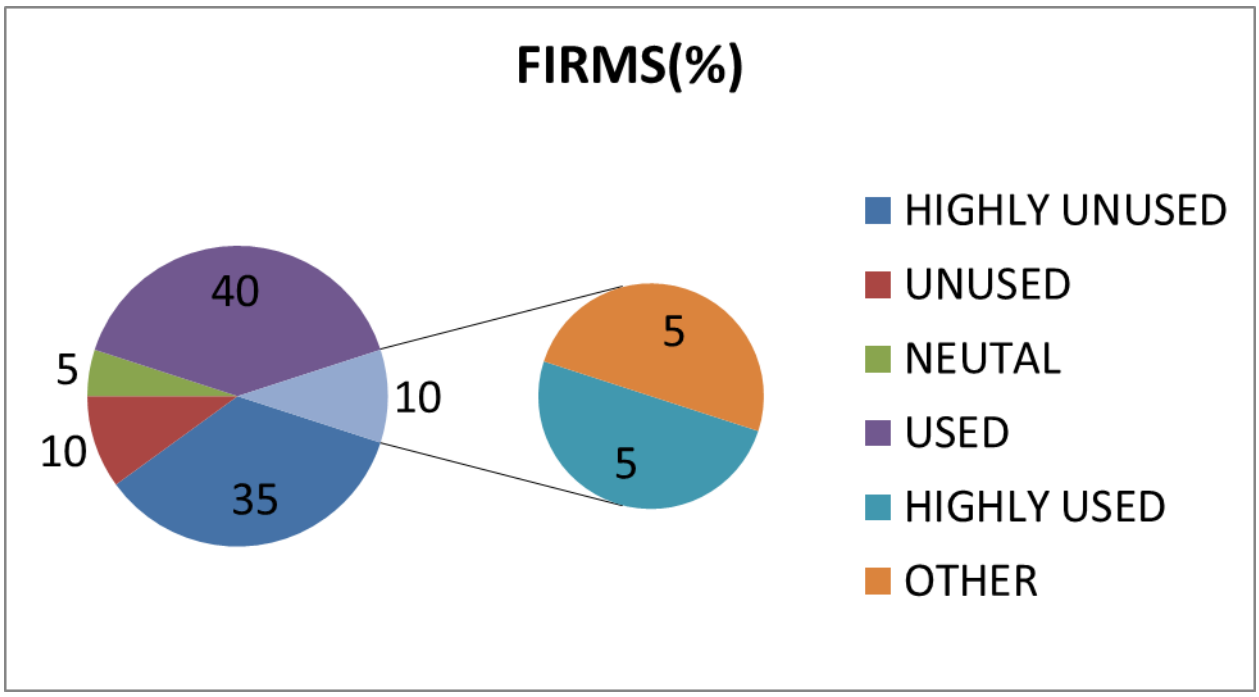

Fig 14. Extent of use of Lean Principles

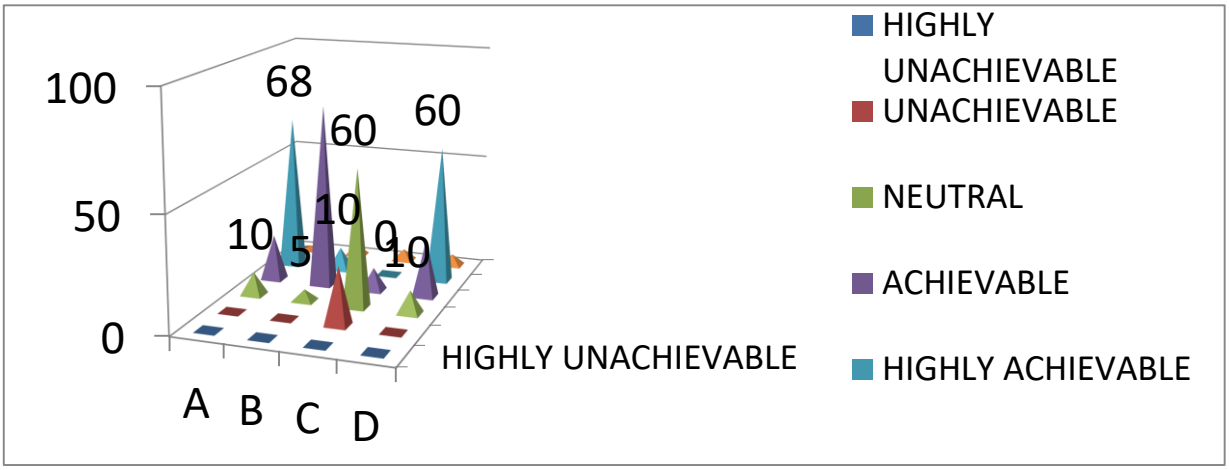

Fig.15. Achievability of Customer Values in Company Operations

• A PERFECT FIRST-TIME QUALITY: ACHIEVING ZERO DEFECTS, REVEALING AND SOLVING PROBLEMS AT THE SOURCE

• B KEEPING EVERYTHING SIMPLE, RIGHT FROM DESIGN THROUGH TO COMPLETION

• C INCREASING OUTPUT FLEXIBILITY: THUS, THE PRODUCTION OF DIFFERENT MIXES AND OR GREATER DIVERSITY OF PRODUCTS, WITHOUT COMPROMISING EFFICIENCY.

• D CONTINUOUS IMPROVEMENT: REDUCTION OF COSTS, INCREASE QUALITY AND PRODUCTIVITY

• F PROMOTE LEAN CONSTRUCTION

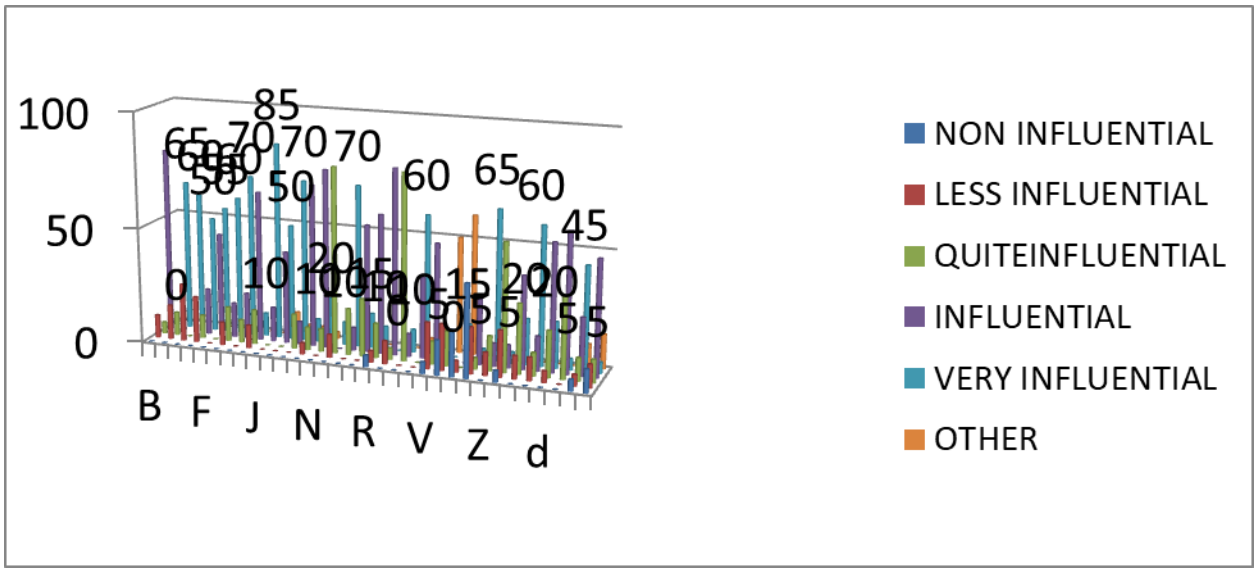

Fig. 16. Barriers to Implementation of Lean Concept

KEY

• A LACK OF INTEREST FROM CLIENTS
• B WASTE ACCEPTED AS INEVITABLE
• C POORLY DEFINED INDIVIDUAL RESPONSIBILITIES
• D LACK OF TRAINING
• E LESS INVOLVEMENT OF CONTRACTORS AND SPECIALISTS IN DESIGN PROCESS
• F DELAYS IN DECISION MAKING
• G LACK OF TOP MANAGEMENT SUPPORT AND COMMITMENT
• H POOR PROJECT DEFINITION
• I DELAY IN MATERIALS DELIVERY
• J LACK OF EQUIPMENT
• K MATERIALS SCARCITY
• L UNSUITABLE ORGANIZATIONAL STRUCTURE
• M LACK OF SUPPLY CHAIN INTEGRATION
• N POOR COMMUNICATION
• O LONG IMPLEMENTATION PERIOD
• P INADEQUATE PRE-PLANNING
• Q LACK OF CLIENT AND SUPPLIER INVOLVEMENT
• R CORRUPTION
• S POOR PROFESSIONAL WAGES
• T LACK OF STANDARDIZATION

- U LACK OF TECHNICAL SKILLS
- V HIGH LEVEL OF ILLITERACY
- W LACK OF AWARENESS PROGRAMS
- X DIFFICULTY IN UNDERSTANDING CONCEPTS
- Y INCOMPLETE DESIGNS
- Z LACK OF BUILDABLE DESIGNS
- a INCONSISTENCY IN GOVERNMENT POLICIES
- b LACK OF AGREED IMPLEMENTATION METHODOLOGY
- c HIGH DEPENDENCY OF DESIGN SPECIFICATIONS ON IN-SITU MATERIALS AND COMPONENTS RATHER THAN STANDARDIZED AND INDUSTRIALIZED PREFABRICATED COMPONENTS
- d EXTENSIVE USE OF SUBCONTRACTORS
- e LACK OF LONG- TERM COMMITMENT TO CHANGE AND INNOVATION
- f LACK OF LONG-TERM RELATIONSHIP WITH SUPPLIER

g THE FRAGMENTED NATURE OF THE CONSTRUCTION INDUSTRY

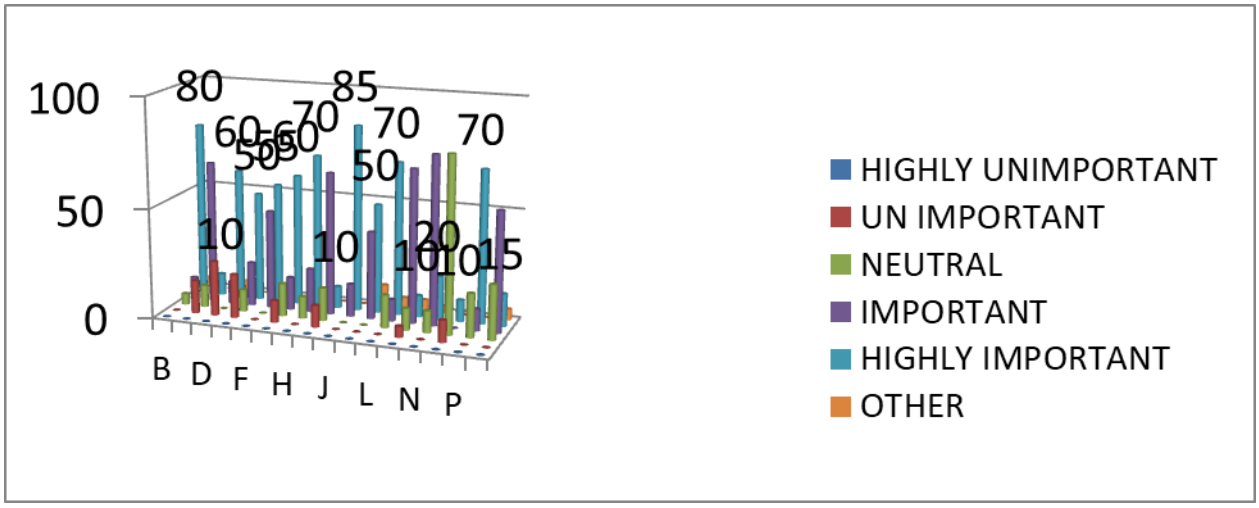

Fig. 17. Measures to overcome Barriers to Implementation of Lean Concepts

- A MANAGEMENT SHOULD TRAIN EMPLOYEES ON LEAN CONCEPTS
- B COMMUNICATION SHOULD BE IMPROVED AMONG PLAYERS IN CONSTRUCTION PROJECTS
- C CONSTRUCTION SHOULD ENSURE OR MAINTAIN CONTINUOUS IMPROVEMENT: THUS, REDUCTION OF COSTS, INCREASE QUALITY AND PRODUCTIVITY
- D CONSTRUCTION MANAGERS SHOULD BE COMMITTED TO CHANGES
- E WORKERS SHOULD BE ABLE TO WORK IN TEAMS
- F PROACTIVE MEASURES TO PREVENT DEFECTIVE PRODUCTION SHOULD BE ESTABLISHED BY FIRMS
- G TIMELY DELIVERY OF MATERIALS TO CONSTRUCTION SITES
- H FIRMS SHOULD UNDERSTAND CLIENT NEEDS AND EXPECTATIONS AND POSITION THEMSELVES ACCORDINGLY
- I COMPANIES SHOULD BE MORE CLIENT FOCUSED
- J STANDARDIZED CONSTRUCTION ELEMENTS SHOULD BE PROMOTED IN THE INDUSTRY
- K FIRMS SHOULD BE WILLING TO CHANGE ORGANIZATIONAL CULTURES THAT DO NOT PROMOTE LEAN CONSTRUCTION
- L THE OPINION OF EMPLOYEES SHOULD BE CONSIDERED IN DECISION MAKING
- M GOVERNMENT AGENCIES SHOULD EMBARK ON APPLICABLE POLICIES THAT COULD PROVIDE CRITICAL SUPPORT TO MAKE LEAN METHODS FEASIBLE

– N MANAGEMENT SHOULD MONITOR INFLATION RISKS AND PRICING LEVELS THAT COULD PROVIDE THE STABILITY THAT ORGANIZATIONS NEED IN ORDER TO MAKE LEAN METHODS FEASIBLE

• O MANAGEMENT SHOULD DEAL WITH UNCERTAINTIES AND FEARS THAT CAUSE ORGANIZATIONS TO CONCEAL INFORMATION INSTEAD OF SHARING IT

• P PARTNERING SHOULD BE PROMOTED TO MAXIMIZE TEAM BUILDING AND DEVELOPMENT OF TRUST

• Q TEAM MEMBERS SHOULD BE EMPOWERED IN DECISION-MAKING TO MAKE THESE PARTNERSHIPS MEANINGFUL

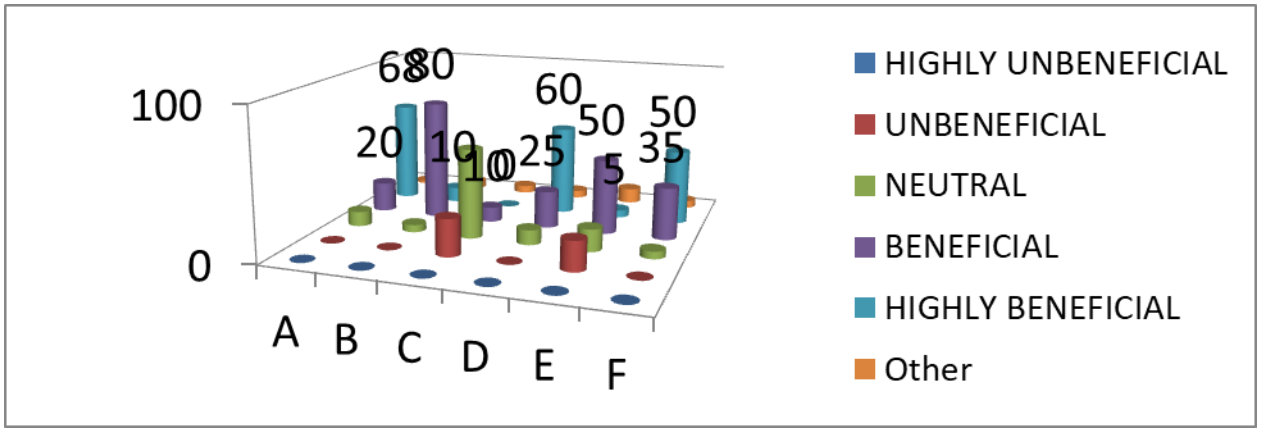

Fig. 18. Benefits of the Implementation of Lean Concept in the Construction Industry

• A DELIVER PRODUCTS OR SERVICES THAT ENABLE CUSTOMERS TO BETTER ACCOMPLISH THEIR GOALS

• B DELIVER PRODUCTS OR SERVICES ON TIME AND WITHIN BUDGET MINIMIZE DIRECT COSTS THROUGH EFFECTIVE PROJECT DELIVERY MANAGEMENT MAKE WELL -INFORMED BUSINESS DECISIONS AT ALL PROJECT LEVELS

• C DELIVERS A CUSTOM PRODUCT, INSTANTLY, WITHOUT WASTE

• D REDUCE SYSTEM NOISE IMPROVE PROJECT DELIVERY METHODS

• E PROMOTE CONTINUOUS IMPROVEMENT IN PROJECT DELIVERY METHODS THROUGH LESSONS LEARNED

• F MINIMIZE RISK AND MAXIMIZE OPPORTUNITY INJECT RELIABILITY, ACCOUNTABILITY, CERTAINTY, AND HONESTY INTO THE PROJECT ENVIRONMENT

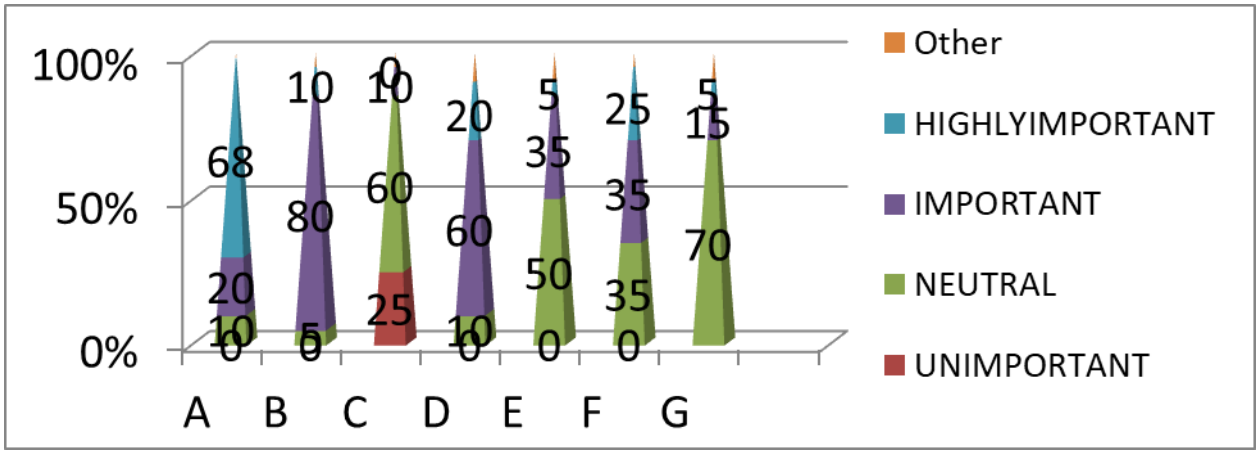

Fig. 20. Measures of Bridging Knowledge Gaps

KEY

• A TRAINING OF EMPLOYEES AT ALL LEVELS ON LEAN CONSTRUCTION

• B ENGAGEMENT OF COMPETENT AND SKILLED SITE OPERATIVES

• C PROMOTION OF THE CONCEPT TO FIRMS, PROFESSIONAL BODIES AND MAJOR STAKEHOLDERS

• D THE CONSTRUCTION INDUSTRY SHOULD FUND WORKSHOPS AND RESEARCH CONFERENCES TO PROMOTE TRANSFER OF KNOWLEDGE ON LEAN CONSTRUCTION

• E WORKING ON IMPROVING PERFORMANCE WHEN CARRYING OUT PROJECTS

• F CONSTRUCTION MANAGERS SHOULD BE COMMITTED TO CHANGES

• G FIRMS SHOULD CHANGE ORGANIZATIONAL CULTURE THAT DOES NOT PROMOTE LEAN CONSTRUCTION

5. Conclusion

The availability of data on material wastage in construction sites was relatively scarce as indicated from reviewed literature. Studies conducted in different countries are small and mostly focused on limited number of materials in a few construction sites. Distinct measurement procedures and different technologies were involved, therefore comparison of the results difficult.

Results from the current study confirmed that the level of waste in the Nigerian construction industry is fairly high and that much of this waste is predictable and avoidable. The fact that some relatively simple and inexpensive preventive measures have not been implemented indicates a lack of knowledge among construction managers about the performance at their sites.

In fact, several managers from the construction sites that took part in the research were surprised by their low performance Indeed; very few of the sites involved in the studies had organized records on the actual delivery, storage, and consumption of materials.

Project control in those companies is mostly based on financial performance measures, which tend to be backward focused and do not make it easy to trace operational costs (Hope, Frazier, 2013).

The analysis of sources of waste indicated that a large proportion of material waste occurs because flow activities, such as material delivery, inventories, and internal transportation and handling, are often neglected by site management. A similar conclusion was found by Bhasin (2015).

It must be pointed out that the waste of materials tends to increase the amount of non-value-adding activities and thereby the waste of other resources such as labor and equipment time. For instance, the excess of material that needs to be purchased tends to increase stocks, the demand of the transportation system, and the effort necessary to remove debris from site. These problems might also negatively affect health and safety conditions.

The current study has summarized the findings deduced from the analysis of available data and related it to the objectives of the study.

The study has identified the main sources and causes of materials waste in the Nigerian construction industry from the perception of construction practitioners. The level of contribution of the waste sources to the generation of waste saw differences between the perceptions of the respondents. A great number (67 %) agree that „design and documentation factors", „procurement factors" and „material handling factors" have significantly high contribution to the generation of waste on construction sites. Operational factors were however, not of significance to some (43 %) since they believed these problems could easily be dealt with if proper management actions are put in place. They considered „materials handling", „operational factors", „design and documentation factors" and „procurement factors" as having high significant contribution to the generation of waste on construction sites. The results showed that whereas the 47 % of respondents identified design and documentation as the major source of waste, 35 % identified materials handling as the major source of waste.

All the fifteen factors evaluated were considered as major causes of design and documentation waste on construction sites. The results further showed that „last minute client requirement (resulting in rework)", „poor communication leading to mistakes and errors",

„selection of low quality products", „designer's inexperience in method and sequence of construction" and „poor/ wrong specifications" are the first five major causes of waste resulting from design and documentation. Other causes of waste include „lack of knowledge about construction techniques during design activities", „lack of attention paid to dimensional coordination of products", „lack of information in the drawings", „poor site layout", „lack of attention paid to standard sizes available on the market", „complexity of detailing in the drawings", „variations in the design while construction is in progress", „designer's unfamiliarity with alternative products", „incomplete contract documents at commencement of project" and „overlapping of design and construction".

The results from the survey revealed that the respondents consider all the seventeen factors as causes of waste arising out of operational activities on construction sites. The results further revealed that „errors by tradesmen or task operatives", „use of incorrect material, thus requiring replacement", „required quantity unclear due to improper planning", „delays in passing of information to the contractor on types and sizes of products to be used" and „poor interaction between various specialists" were the first five major causes of waste that arise out of operational activities on construction sites. Other equally important causes of operational waste are „unfriendly attitudes of project team and task operatives", „choice of wrong construction method", „damage to work done caused by subsequent trades", „inappropriate placement of the material", „accidents due to negligence", „equipment malfunctioning", „inclement weather", „poor technology of equipment", „effects of political and social conditions", „shortage of tools and equipment required", „frequent breakdown of equipment" and „difficulties in obtaining work permits".

The findings revealed that „purchasing products that do not comply with specification", „unsuitability of materials supplied to site", „substitution of a material by a more expensive one", „ordering errors" and „changes in material prices" are the major causes of waste arising out of procurement activities.

It was established from the survey that „lack of onsite materials control", „damage to materials on site during transportation", „poor handling of materials", „waste resulting from cutting uneconomical shapes" and „using excessive quantities of materials than required" are the major causes of waste arising from materials storage and handling. The results further revealed that „overproduction/ production of a quantity greater or required than necessary", „theft", „poor method of storage on site", „manufacturing defects," „unnecessary inventories on site leading to waste", „use of whatever material close to working place", „insufficient instructions about handling", „use of wrong method of transport" and „overloading of transport equipment" are other important causes of materials waste arising from storage and handling.

Timber, cement/mortar, concrete, blocks, steel, quarry chippings/ coarse aggregates, paint, sand and tiles are the key materials wasted on construction sites. The results showed that all the materials with the exception of pipes have high levels of contribution toward the generation of waste on construction sites.

The respondents considered all the 26 measures as important for minimizing wastage of materials on site. The results further showed that „purchasing raw materials that are just sufficient, using materials before expiry dates, good coordination between store and construction personnel to avoid over ordering, „use of more efficient construction equipment and „adoption of proper site management techniques are the five most important measures which can minimize the wastage of materials on construction sites. The least but important measures identified by the respondents include „encouraging re-use of waste materials in projects , „use of low waste technology (WMM 12)" and „recycling of some waste materials on site .

The study has provided empirical evidence on the levels of contribution and the levels of practice of waste minimization measures in the Nigerian construction industry. It has shown that purchasing raw materials that are just sufficient, using materials before expiry dates and use of more efficient construction equipment are perceived as the three measures that most significantly contribute to waste minimization and also the most practiced waste minimization measures. Encouraging re-use of waste materials in projects, using low waste technology and recycling of some waste materials on sites are, however, perceived as the least significant factors that contribute to waste minimization and the least practiced measures simply because such measures are seen as adding to their production cost instead of reducing cost.

Analysis of the results obtained from the structured questionnaire survey showed the existence of some level of awareness among professionals in the Nigerian construction industry on the concept of lean construction. Principles adopted by construction organizations in their activities such as „delivering what the client wants", „establishing continuous improvement", „constantly seeking better ways to do things", „waste minimization" and „avoiding defects in works done" are observed to be generally consistent with lean construction practice. Majority of the construction professionals surveyed are receptive to lean principles implementation in the construction industry, and are also of the opinion that the transfer of lean construction principles into the construction industry would bring a lot of benefits including „improvement of project delivery methods" and „delivery of products or services that enable clients to better accomplish their goals".

Among the factors identified by construction organizations and consultancy firms as potential barriers to the implementation of LC, factor analysis enabled 26 of them to be placed under six categories: 1) lack of proper planning and control comprising delays in materials delivery, inefficient use of quality standards, long implementation period, waste accepted as inevitable, inconsistency in government policies, high dependency of design specifications on in-situ components and materials, extensive use of subcontractors, lack of long term commitment to change and innovation, lack of long term relationship with suppliers, delays in decision making and materials scarcity; 2) Lack of teamwork comprising the fragmented nature of the industry, lack of interest from clients, poorly defined individual responsibilities and less involvement of contractors and specialists in design process; 3) Poor project management comprising poor project definition, lack of equipment, lack of agreed implementation methodology and unsuitable organizational structures; 4) Lack of technical capabilities comprising lack of buildable designs, incomplete designs and lack of standardization; 5) Lack of professional motivation comprising poor professional wages and corruption; 6) Poor communication between parties comprising difficulty in understanding lean concepts and poor communication.

The results revealed that the five most significant measures to overcome potential barriers to implementation of LC in the Nigerian construction industry are „management should train employees on lean concepts", „communication should be improved among players in construction projects", „construction should ensure or maintain continuous improvement: thus, reducing costs, increasing quality and productivity", „construction managers should be committed to changes", and „the ability of workers to work in teams".

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