CRITICAL EVALUATION OF CONSCIOUS AND UNCONSCIOUS CONSTRUCTION RESOURCES WASTEFULNESS TOWARDS ACHIEVING SUSTAINABLE CONSTRUCTION

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ABSTRACT

Currently construction resources are not only scarce, but also increases in cost; thus, for the construction industry to become truly sustainable, the industry has to re-engineer towards lean principles where the requirement for effective resources waste management is considered paramount. Sustainable Construction follows directly from the necessity to satisfy the needs of construction industry stakeholders and the requirements of future generations. This paper identifies, evaluates and proposes an effective management framework that could support sustainable construction through efficient utilisation of construction resources and avoidance of conscious and unconscious resources wastefulness. Initial facts and insights were obtained through a detailed review of literature, augmented by primary data acquired by means of questionnaires and interviews with construction practitioners. The data collected were analysed using SPSS and NVivo statistical packages. These data and information are collected within the UK construction industry. Findings from the research highlight that, majority of these resource wastes termed unavoidable are avoidable. In respect of these, minimisation of conscious and unconscious resources wastefulness and efficient utilisation of resources are absolutely essential towards enhancement of sustainable construction. The proposal outlined in this paper will significantly enhance the efficient utilisation of construction resources and perpetuate sustainable construction, if properly implemented.

Keywords: Conscious resources wastefulness, construction resources management, lean construction, sustainable construction, unconscious resources wastefulness

1. INTRODUCTION

The active campaigning for sustainable construction follows directly from the necessity to satisfy the needs of construction industry stakeholders and the requirements of future generations. These needs are tailored towards meeting social, economic and environmental importance that can be evaluated by means of life cycle assessment. For the construction industry to become significantly sustainable, the industry has to re-engineer towards lean principles, where requirements for effective resource wastes management need to be considered as paramount.

A literature review forms the basis for this study, and subsequently, quantitative and qualitative survey methods for primary data collection. Primary data are collected by employing quantitative research method approach, while the results of the quantitative study are investigated further by interviewing practicing construction professionals for validity rationale. The emergence results from the interview survey are transcribed, analysed and presented. The Statistical Package for the Social Sciences, (SPSS), version 13 and NVivo, version 2, software are employed for collation and analyses of the quantitative and qualitative data respectively. These data and information are collected within the UK construction industry.

Findings from the research are grouped and presented on three major headings of which the study

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framework is based. Firstly, the study evaluates and establishes several modes of wastes' occurrences: the wastes due to materials, manpower, machinery, production information, design team, and site management. Secondly, the study ascertains the resources' wastes that often occur consciously and unconsciously during the construction production process, and finally, it establishes the avoidable and unavoidable resources' wastes. Subsequently, conclusion of this study is drawn based on the key issues established on these conscious, unconscious, avoidable and unavoidable resources' wastes.

2. CONSTRUCTION SUSTAINABILITY IN CONTEXT

Sustainability is a form of development which intends to meet the present needs of humans without compromising the ability of meeting the needs of future generations, (Brundtland, 1987) . The objectives of the development are to improve resource efficiencies, overall effectiveness and social responsibility. Sustainability concepts involve creation of better quality of life and to ensure that sufficient resources remain for future generations. This concept agitate on circumstances towards improving quality of life for everyone without increasing the use of natural resources beyond the capacity of the environment to supply the resources indefinitely, (OGC, 2007; and BERR, 2007).

The Department for Business Enterprise and Regulatory Reform, (BERR, 2007), suggests a few strategic key areas for sustainable construction, including:

- Reduction of the carbon footprint of activities within the construction sector
- Production of zero net waste at construction site
- Developing voluntary agreement and initiatives between construction industry and its clients with aims of reducing carbon footprint and efficient use of resources that are available within built environment
- Creating a dynamic construction industry by improving skills, boosting numbers of workers that take part in training programmes and retaining skilled workers in the industry

In moving towards sustainability in construction, the industry has to improve environmental responsibility, social awareness and economic profitability. These factors are notionally endorsed to be "The Three Pillars of Sustainability" which influence all aspects of the sustainable decision making process, (Arthur, 1997; BERR, 2007; CIOB, 2006; OGC, 2007; and DEFRA, 2001). Hence, these "three pillars of sustainability" significantly tend towards balancing the conflicting needs of humans.

Sustainability, as a concept has different meaning from one sector to another, and different issues become relevant to different sets of people, more-so, approaches differ from different perceptions. The construction industry tends to address sustainability by asking such questions as, "What? Where? Why? How, and When to build? And, in decision making, the industry takes into considerations, these three pillars of sustainability factors: the social, economic and environmental sustainability, (Construction Skills, 2007).

The guiding principles and approaches towards construction sustainable development as stated in DTI, (2004), are as follow:

- Putting people at the centre so that the individuals could enjoy a better quality of life currently and subsequently
- Taking long term preparations through radical improvements from present time, and consistently safeguarding the interest of future generations
- Placing cognisant account of cost and benefits including those that cannot be easily valued in monetary terms, and
- Creating an open and supportive economic system that could supports economic growth

However, sustainable construction does not only help the environment, but also improves economic profitability and relationship of stakeholders. The practice is to identify what are current good practices within the industry and to improve these current practices, in cognisance of what the future priorities should be.

Achieving sustainability in resources utilisation, construction organisations need to recognise the immense importance of designing to minimise resource wastefulness while achieving targeted quality. Thus, it is therefore paramount to critical evaluate conscious and unconscious construction resources wastefulness occurrences before and during building production towards achieving sustainable construction.

Towards achieving sustainable construction and reduction of conscious and unconscious construction resources wastefulness, Modern methods of construction are paramount. Modern Methods of Construction, (MMC) are the initiation and execution of projects from inception to

completion considering the economy of production, while delivering better quality with minimum delivery times, (BURA, 2005; and National Audit Office, 2005). Among key principles and practice of MMC are the adoption of effective lean construction, partnering and the supply chain systems. Based on these approaches, construction organisations strive towards delivering products more efficiently, cheaper and faster.

Lean construction, (LC); a production management-based approach to project delivery, a new way to design and build capital facilities, and to change the way in which projects, work, and tasks are being carried out, that is, the delivery process. Lean construction extends from the objectives of a lean production system by structuring production processes in order to maximise value and minimise waste through specific techniques and apply the techniques throughout the project delivery processes, (Constructing Excellence, 2006). Some of these initiatives and practice are Lean Project Delivery System, (LPDS), Construction Lean Improvement Programme, (CLIP), Construction Best Practice, (CBP), Constructing Excellence, (CE), and Construction Key Performance Indicators, (KPI). The operations of these LPDS features enhance efficient application of construction resources in the industry, and bring forth clients' satisfaction and also enhance contractors' profitability. The Construction Lean Improvement Programme, (CLIP) is another initiative towards achieving efficient resources utilisation that fosters sustainable construction. This concept focuses companies on achieving significant levels of clients' satisfaction by improving the quality, cost, delivering of products, and services at satisfactory efficiency, (BRE, 2006). Thus, efficient and effective implementation of lean construction principles will significantly enhance construction industry in removing several non - essential wasteful activities, and to minimise non - value adding activities in order to achieve optimal construction resources waste management.

Partnering and the supply chain are concepts towards sustainable construction, by which two or more organisations co-operate to find ways of working together that could serve a significant interest of the parties, (Peace and Bennett, 2006; and in National Audit Office, 2001; Construction Industry Council, 2005; and CIOB, 2006). Among the advantages of these concepts are achieving good performance in respect of quality, time, cost and specific improvement over individual distinctive skills. Moreover, the partners tend to co-operate together over a series of projects to achieve improvements on performance that often leads to efficient resources utilisation, greater productivity, minimisation of conscious and unconscious resources wastefulness, and thereby improved profit.

3. RESEARCH METHODOLOGY

This research work examined conscious and unconscious resources wastefulness optimal resources utilisation, during construction project execution. Detailed literature reviews were carried out, followed by primary data collection, acquired through both quantitative and qualitative research methods, for triangulation purposes and in order to achieve valid findings. Questionnaires were distributed to construction site managers working in different organisations, and extensively covered all geographical regions in the UK. One hundred and two questionnaires were collected from experienced site management personnel and analysed using a Statistical Package for the Social Sciences, SPSS version 13.

The respondents were solicited to classify construction resources wastefulness into conscious or unconscious in relation to occurrence, and avoidable or unavoidable in relation to avoidance during utilisation. That is, to classify each waste, either the occurrence is conscious or unconscious in nature; also, to indicate either the occurrence is avoidable or unavoidable. The frequency of the occurrence was rated from “very high occurrence”, (5) to “very low occurrence”, (1). The findings are presented in form of tables, figures, and interactive charts to draw the relationships between the factors considered. The reliability and validity of the items data collected were verified with ANOVA, and chi-square statistics tests; these ascertained the consistencies of the respondents’ responses, and the items data correlations. The quantitative survey results are presented in section 4.

In addition, to validate the quantitative survey findings, questions were structured from the results, which served as a guide for a qualitative interview survey. Eight experienced site managers were interviewed. The interviews were tape-recorded using a digital recorder and uploaded to a computer and analysed using NVivo 2 statistical software. The interviews were firstly transcribed verbatim, and then coded to various significant nodes and themes on sequence of occurrences. Information obtained were further clustered and grouped together to a logical order of understanding. Findings from the qualitative survey study were summarised succinctly including explanations. The study findings and

the established facts and issues obtained from this interview survey are presented in section 5.

4. DATA ANALYSIS AND DISCUSSION OF FINDINGS

- ***Quantitative research survey***

The quantitative research survey is sub-divided into three main categories. Firstly, the study evaluates several modes of wastes' occurrences: the wastes due to materials, manpower, machinery, production information, design team, and site management. Secondly, the study ascertains the resources' wastes that often occur consciously and unconsciously during the construction production process, and finally, it establishes the avoidable and unavoidable resources' wastes.

- **Discussion of Findings of "Avoidance of Construction Resources Wastefulness", (ACRW) - Wastes due to Materials' Circumstances:**
  - ***Sources of occurrence:*** Frequency of the occurrence of thirteen distinct factors that causes materials' wastes are presented in Table 1. It is found that materials' wastes due to "damage on stock piling," "materials off-cut" and "specification error(s)" are significant during construction works, while the least-occurring ones are "transit wastes – spillage and breaking" and wastes due to "planning mistakes". The percentages of all the factors, (Table 1), are approximately average, ranges from 46% to 59%. However, the CRWM research study is on "avoidance or minimisation of resources wastefulness". Thus, there is a significant need to evaluate and ascertain the modalities of averting the occurrence of these wastes. The interview research study ascertained the several possible solutions, and these solutions are presented in Section 4.2.
  - ***Modes of occurrence and the avoidance:*** Figure 1 presents the conscious and unconscious modes of occurrence of all the factors considered on materials' wastes. Figure 2 presents the occurrence of these factors in relation to whether they are avoidable or unavoidable during resources utilisation.

    The interactive chart, Figure 1, indicates that approximately 50% of these factors occur consciously, while the other 50% occur unconsciously. However, Figure 2 shows that the majority of these factors considered are avoidable; Eleven (11) out of thirteen factors have a very high percentage, rated above 63%. Therefore, this affirmed that the modes of occurrence of the majority of materials' wastes are avoidable during construction production process. In respect of this, further investigations were made through interview research survey, (Section 4.2), which established the possible modalities of averting and/or minimising these predicaments.

    Based on reliability and validity tests' statistics conducted on all variables obtained on "wastes due to materials", deductions could be made that the items data obtained are consistent and valid, apart from materials' wastes due to "specification error(s)" in which "Cronbach's Alpha Coefficient" is greater than the "Total Overall Alpha Coefficient", indicating that if this item "specification error(s)" is deleted from the calculation, the overall total will be 0.893 instead of 0.883.
- **Discussion of Findings of Avoidance of Construction Resources Wastefulness, (ACRW) - Wastes due to Labour Circumstances:**
  - ***Sources of Occurrence:*** The frequency of occurrence of wastes due to labour circumstances is presented in Table 2. The main identify factors of the resource wastefulness are due to "double handling" and "rework due to mistake(s)". The least factor that causes wastes is "over staffing for a particular work operation". All these factors are further investigated to ascertain the modes and causes of the occurrence, and to establish the possible modalities of reducing the occurrence. These facts are presented in Section 6, (the interview research survey report).
  - ***Modes of occurrence and the avoidance:*** The modes of conscious and unconscious occurrence of labour wastes are presented in an interactive chart, Figure 3. This chart shows that majority of labour wastes occur unconsciously; only three (3) out of the twelve factors considered occur consciously.

    However, Figure 4 indicates that, the majority of these items wastefulness could be averted, (avoidance percentage above 70). Only one factor is found to be unavoidable,

(Mp6, Weather condition that delays work operation). These findings prompted further investigations to ascertain the rationales for these circumstances and to establish the modalities of enabling these unconscious wastes' scenarios being conscious and be averted; to minimise resources wastefulness during production process. The findings obtained from the interview research survey conducted are presented in Section 6.

Table 1: Frequency of Occurrence - Wastes due to Materials

Wastes due to Materials	Factors' Notations	% Freq. of Occurrence
1) Materials damage on stock piling.	Ma 1	59
2) Off-cut due to irregular shapes.	Ma 2	55
3) Design not to manufacturer(s) standard - materials off cut.	Ma 3	55
4) Specification error(s).	Ma 4	51
5) Over ordering due to quantity surveyor mistake.	Ma 5	50
6) Pilferage.	Ma 6	50
7) Weather condition - materials spoilage.	Ma 7	49
8) Over ordering due to Design engineers faults.	Ma 8	49
9) Residual and spillage during work in progress.	Ma 9	48
10) Drying shrinkage due adverse weather.	Ma 10	48
11) Excess ordering of materials. For usage, (unreturned to store).	Ma 11	47
12) Transit waste - braking and spillage.	Ma 12	47
13) Planning mistake.	Ma 13	46

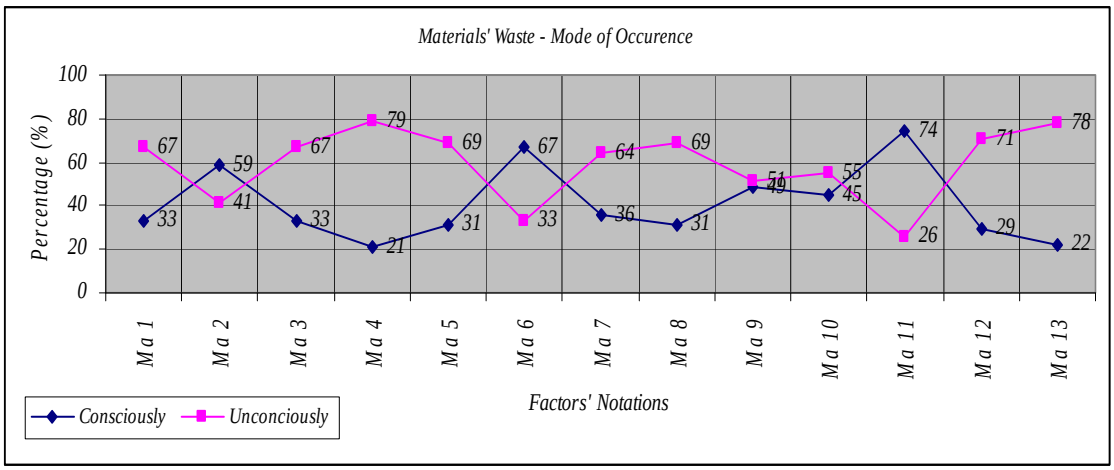


Figure 1: Modes of occurrence – Wastes due to Materials, (Ma1 - Ma13 notations in Table 1)

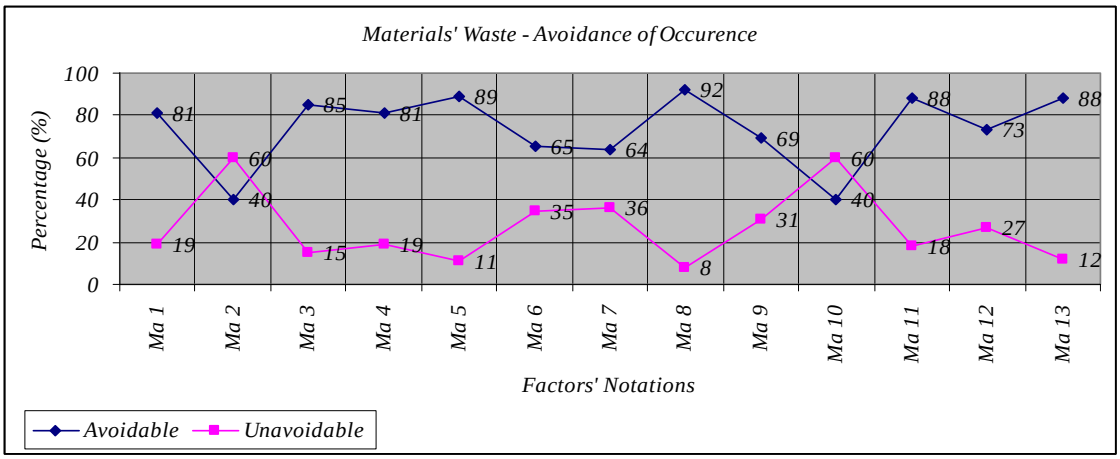


Figure 2: Avoidance of the Occurrence –Wastes due to Materials (Ma1 - Ma13 notations in Table 1)

Table 2: Frequency of Occurrence - Wastes due to Labour Resource Utilisation, (Mp) and The Notations used in the figures

Wastes due to labour	Factors' Notations	Freq of occurrence %
1) Double handling.	Mp 1	60
2) Rework due to mistakes.	Mp 2	58
3) Unskilled operation - increasing completion time.	Mp 3	54
4) Waiting time for the resources to be used - redundancy period.	Mp 4	54
5) Lack of coordination among gang.	Mp 5	51
6) Weather condition - work delay.	Mp 6	51
7) Insufficient tools and equipment for use - waiting time.	Mp 7	50
8) Wrong construction method - leading to time delay	Mp 8	49
9) Less work apportionment.	Mp 9	48
10) Right operation for wrong work – leading to delay or rework.	Mp 10	48
11) Traffic between plant positions to operation place.	Mp 11	48
12) Over staffing for a particular work operation.	Mp 12	46

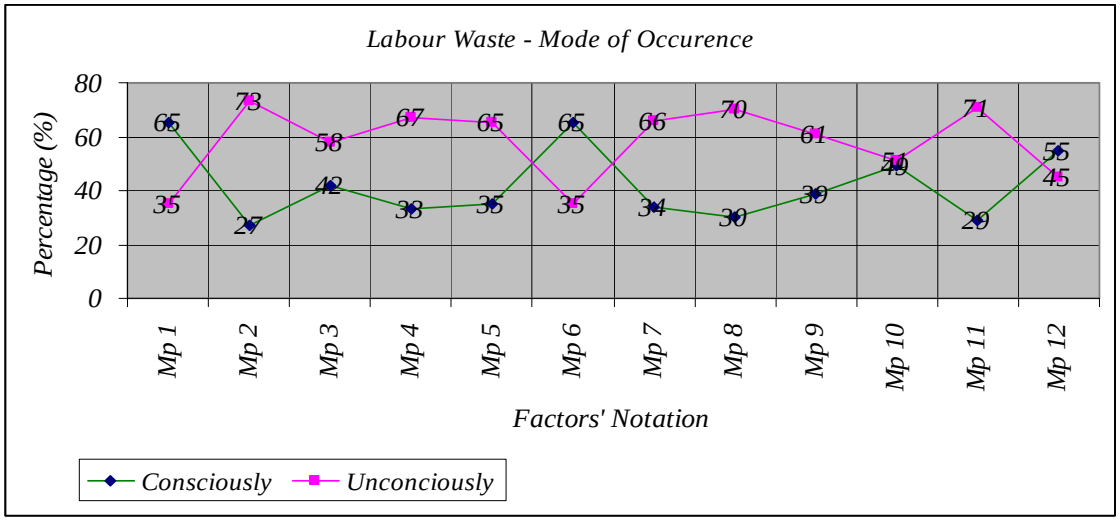


Figure 3: Modes of the Occurrence – Wastes due to Labour Resource, (Mp1 to Mp12)

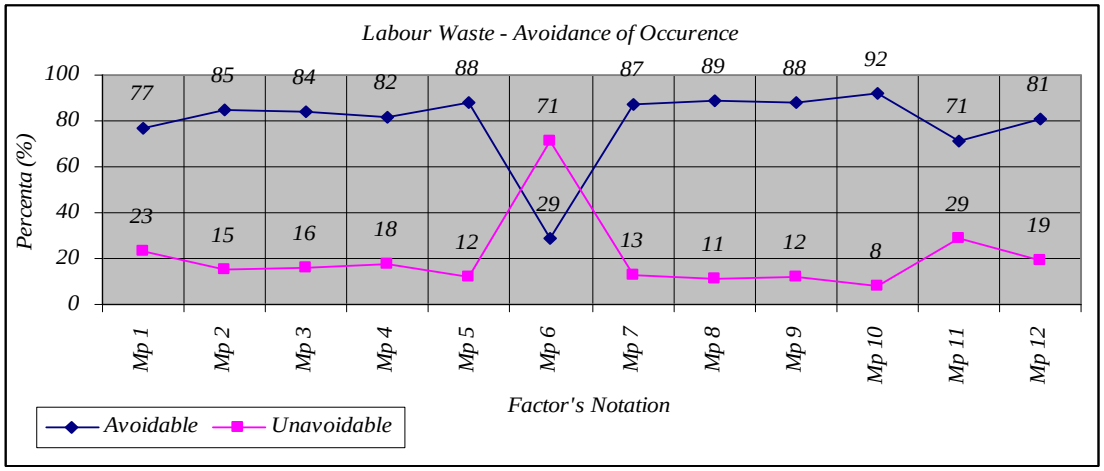


Figure 4: Avoidance of the Occurrence – Wastes due to Labour Resource, (Mp1 to Mp12)

Reliability and validity Tests' Statistics of all the variables considered on wastes due to Labour circumstances are verified. Inferences were be drawn that the data obtained from the respondents on these items are reliable, apart from that obtained on "weather condition - work delay" having "corrected item – total correlation less than significant value of 0.3 and the Cronbach's Alpha if deleted of 0.917. This alpha coefficient indicates that, if the item is deleted "Total Cronbach's Alpha coefficient" will be 0.917 instead of 0.637. Further, the Chi-Square and ANOVA tests' statistics values indicate that there are significant relationships between the items, (value < 0.05).

- **Discussion of Findings - Avoidance of Construction Resources Wastefulness, (ACRW) - Wastes due to Plant and Equipment Circumstances:**
  - ***Sources of Occurrence:*** As defined in this research work, resources' wastes refer to utilisation of construction inputs that do not add value to the outcome of the product(s). These arise through inefficient utilisation of resources, (Materials, Manpower, and Machinery), and these wastes could be solid, (physical) or latent, (not physical), in nature.

    The frequency of occurrence of wastes due to plant and equipment circumstances is presented in Table 3. From this table, the occurrence of wastes of the considered factors are significant, (49% and above). Though, the occurrence of wastes due to "low out capacity than require of the gang in operation" rate is the highest, (56%). Each factor considered contributed to construction plant and equipment inefficiencies during production process. Further investigations to ascertain these findings and to establish the modalities of reducing these predicaments are verified and presented in interview research survey Section five.

    As illustrated in Figure 5, it shows that 50%, (ten out of twenty) of the considered factors on wastes due to machinery scenarios occur consciously, while others occur unconsciously.

    However, by relating these consciousness occurrences to avoidance of the occurrences, Figure 6 shows that all the wastefulness are avoidable, with very high avoidance rates (above 70%), apart from one factor with a rate of 52%. These findings ascertained that resources' wastes due to machinery utilisation are avoidable, (Mean value is 83%), during construction process; these made the needs to ascertain the rationales of the occurrences. Further investigations were carried out to establish these facts and modalities of averting the occurrences, (Section 6).
  - ***Modes of occurrence and the avoidance:*** Comparing the mean percentages of the different modes, the occurrence of wastes due to plant and equipment utilisation is more unconscious in nature with a mean percentage of 56%, (Table 4).

    The data collected reliability and validity tests were calculated to check the consistency and strengths of relationship of the data set, items and respondents' responses, through employing reliability tests' statistics; ANOVA (F-test), and Chi-square test for goodness of fit.

Table 3: Frequency of Occurrence - Wastes due Plant and Equipment Circumstances

Wastes due Plant and Equipment	Notations	Frequency (%)
1) Low output capacity than required of the gang in operation.	Me 1	56
2) Operation and plant position, traffic – materials and labour waste.	Me 2	54
3) Position/stationary un-used, rental cost.	Me 3	53
4) Breakdown during work in progress - material/labour waste.	Me 4	53
5) Early delivery time and redundancy period.	Me 5	52
6) Uncoordinated skill of plant operator and controller.	Me 6	50
7) Lack of coordination within gang - redundancy/inefficiency.	Me 7	50
8) Wrong construction method and repeated work for plant.	Me 8	50
9) Un-experience operator - minimal efficiency/productivity.	Me 9	49
10) Poor communication system within the gang - time lag.	Me 10	49

The "Corrected Item-Total Correlation" of individual factors is greater than the acceptable value of 0.03, and the corresponding "Cronbach's Alpha Coefficient if Item is deleted" values are all less than the "Total Cronbach's Coefficient" value, (0.941), These indicate that the items respondents' responses are significantly consistent and reliable.

Also, the statistics results show that, the ANOVA and the chi-square values of individual factors are less than standard significance level of 0.05. These indicate that there is strong concordance between the items.

Table 4: Mode of Occurrence - Wastes due Plant and Equipment

Waste due Plant and Equipments	Conscious	Unconscious	Avoidable	Unavoidable
Mean of Occurrence (%)	44	56	83	17

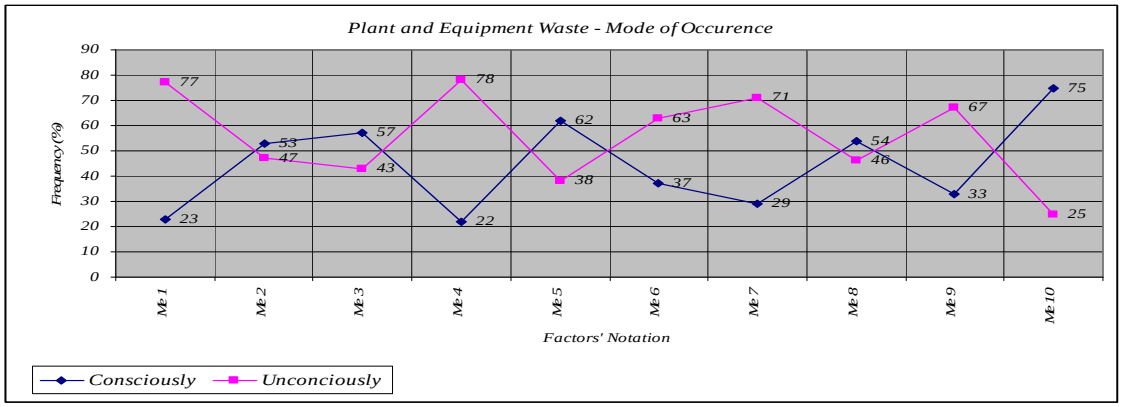


Figure 5: Mode of occurrence – Wastes due to Plant and Equipment (Me1 to Me10)

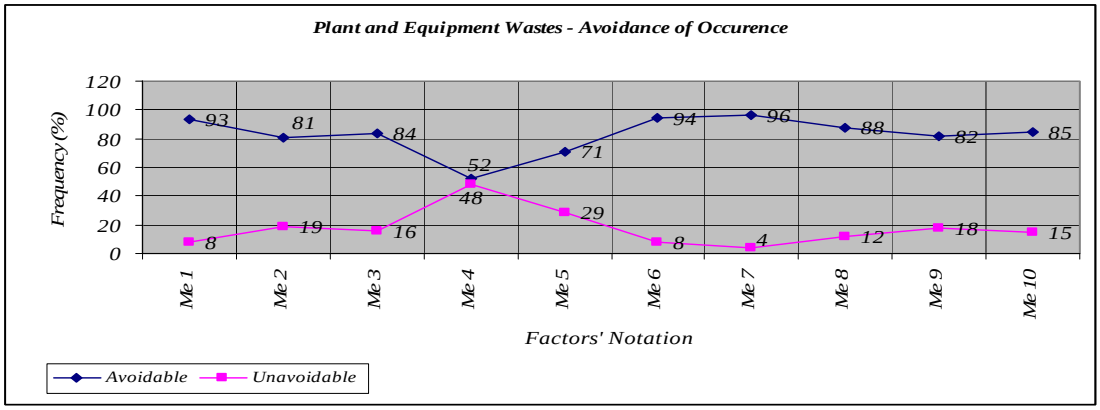


Figure 6: Avoidance of the Occurrence - Wastes due to Plant and Equipment - (Me1 to Me10)

- **Discussion of Findings from "Avoidance of Construction Resources Wastefulness", (ACRW) - Wastes due to Production Information Circumstances:** The frequency of occurrence of wastes due to production information is presented in Table 5. The occurrence of wastes due to "Inadequacy of architectural specification(s)" is the highest, (60%), followed by "Design error", (57%). From the results obtained on the eleven factors considered, it shows that the occurrence of wastes due to production information is significant, (the minimum rate of occurrence is 51%).

  The modes of occurrence of wastes, (both conscious and unconscious), due to production information are presented in Table 5; while the details of occurrence are shown in interactive chart Figure 7. Also, Figure 8 shows the possibility of avoiding these types of resources' wastes during construction process.

  From the Figure 7, it could be observed that the majority of the wastes due to production information occur unconsciously with occurrence rates above 60% and the average percentage of unconsciousness is 62% (Table 5). Also, the occurrences of these factors are easily avoidable; several factors are rated above 70%, (Figure 8), and the average avoidance rate is 80%, (Table 5).

  Based on the results presented in Figures 9 and 10, a deduction could be inferred that the majority of the wastes due to production information occur unconsciously and the occurrence could be avoided. However, further investigations were made to validate these findings and to establish how these predicaments could be minimised towards achieving optimal utilisation of the construction resource during production process. These possible solutions are presented in Section 6 in the interview research survey report.

  The reliability and validity tests' statistics of the variables are considered on the occurrence of wastes due to Production Information. The following facts are obtained:

  - Corrected Item-Total Correlation: All items value > 0.3
  - Cronbach's Alpha if Item Deleted: All items value < Total Cronbach's Alpha coefficient value (0.898)
  - Chi- Square is significant < 0.05; and
  - ANOVA (F-test) is significant < 0.05

  Thus, deduction could be made that the data collected are significantly reliable and valid. However, further investigations are made, (interview research survey report in Section 6), that ascertained these findings and established modalities of averting or minimising the occurrences of these scenarios.

Table 5: Frequency of Occurrence - Wastes due to Production Information

Wastes Due To Production Information	Notations	Freq.
1) Inadequacy of Architectural specifications.	Pi 1	60
2) Design errors.	Pi 2	57
3) Architectural drawings complexity and interpretation time lag.	Pi 3	56
4) Variation order and implementation approval delay.	Pi 4	55
5) Modifications subjected to due process for implementation.	Pi 5	55
6) Inadequacy of Electrical Engineering specifications.	Pi 6	53
7) Inadequacy of Structural Engineering specifications.	Pi 7	53
8) Ambiguity of Structural Drawings and interpretation time lag.	Pi 8	53
9) Inadequacy of Mechanical Engineering specifications.	Pi 9	52
10) Alterations subjected to due process for implementation.	Pi 10	51
11) Inadequacy of Estimator/Quantity Surveyor specifications.	Pi 11	51

Table 5: Average Mode of Occurrence of the all factors Considered - Wastes due to Production Information

Wastes Due To Production Information	Conscious	Unconscious	Avoidable	Unavoidable
Mean of Occurrence (%)	38	62	80	20

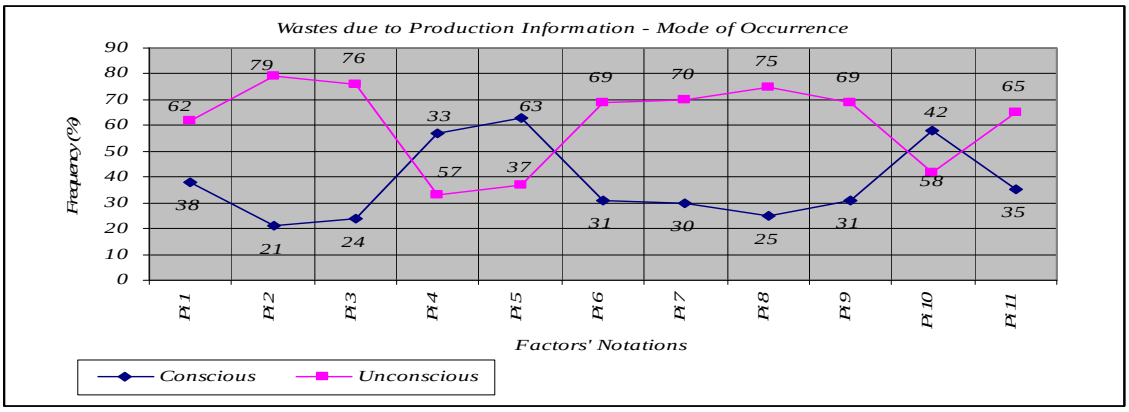


Figure 9: Modes of Occurrence - Wastes due to Production Information

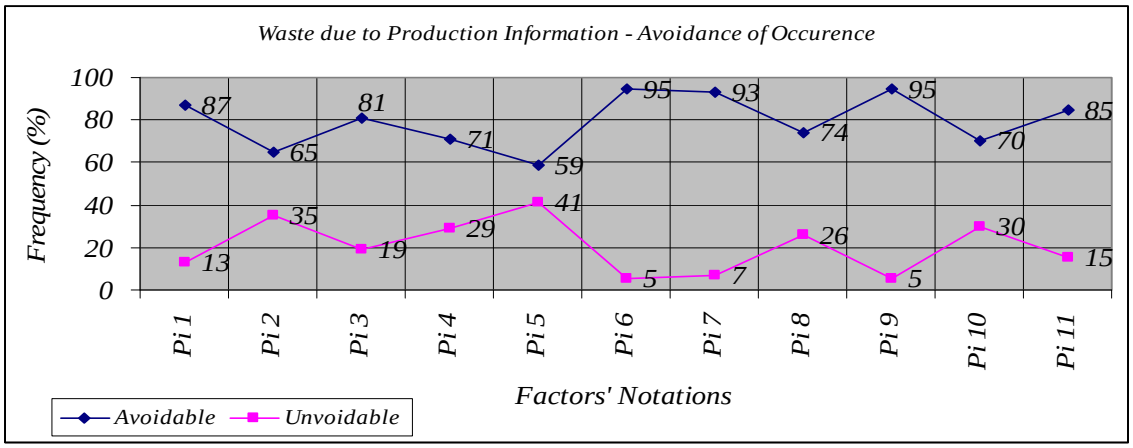


Figure 10: Avoidance of Occurrence - Wastes due to Production Information

- **Discussion of Findings from "Avoidance of Construction Resources Wastefulness", (ACRW) - Wastes Due To Site Management Circumstances:** The causes of wastes occurrence due to site managers' inefficiencies are presented in Table 6. The result shows that significant percentages of resources are wasted due to inadequate planning and organisation of the resources before the commencement of construction project (60% and 57% respondents support respectively). All eleven factors considered have rates of 50% and above, apart from one, (48%).

Table 6: Frequency of Occurrence - Wastes due to Site Managers' inefficiencies

Wastes due to Site Management	Factors' Notations	Frequencies of Occurrence
1) Inadequate planning of resources before project commences.	SM 1	60
2) Inadequate site organisation that often lead to wastages.	SM 2	57
3) Inadequate operation control.	SM 3	54
4) Inadequate project schedule that do lead to wastage.	SM 4	54
5) Delay in decision taking of construction - task operation time lag.	SM 5	54
6) Inadequate monitory systems.	SM 6	54
7) Ineffective "up-down" communication between construction participants.	SM 7	54
8) Poor schedule of resources that leads to wastage.	SM 8	53
9) Inexperience of the technicality require for a task.	SM 9	50
10) Lack of sufficient motivation that could enhance operative	SM 10	50

morale. 11) Poor selection of materials and procurement of labour.	SM 11	48

Table 6: Modes of Occurrence - Wastes due to the Site Management

Wastes due to Site Management	Con	Uncon	Av	Unav
Average of the Occurrences (%)	33	67	79	21

These results indicate that, inefficient utilisation of construction resources due to site managers is significant, which illustrates the significant role of site managers in resources efficient utilisation, and further highlights the need to critically evaluate and ascertain the issue of, "How site managers' efficiency and performances could be enhanced (Section 5.3)," in order to establish the modalities of achieving optimal resources utilisation during construction production process.

Further investigations are carried out on the causes of site management inefficiency that resulted in resources wastefulness, to ascertain the factors consciousness in occurrence, and also, to classify these factors in relation to avoidance of the inefficient resources utilisation.

Table 7 shows the mean of occurrence of wastes due to the site management; the average of unconsciousness rates is 67%, while the avoidance rates average is 79%. Figures 11 and 12 illustrate the detail characteristics of all factors considered, and these figures show that the causes and occurrences of these factors are significantly unconscious and avoidable. None of the factors avoidance rate is less than 71%, apart from "Inexperience of the technicality require for a task", (63%).

These results are subjected to further investigation to investigate:

> *"Why site managers are not conscious of resources' wastes occurrences, and how could the site management consciousness be improved, towards achievement of an enhanced resources utilisation and wastes minimisation?"*

Also, based on these findings, interview research survey was carried out to establish an effective means of avoiding or minimising these predicaments. The findings obtained from the interview research survey are presented in Section 6.

The reliability and validity tests' statistics of all the variables considered on occurrence of wastes due to Site Management are tested. The following facts were obtained:

- Corrected Item-Total Correlation: All items value > 0.3
- Cronbach's Alpha if Item Deleted: All items value < Total Cronbach's Alpha coefficient value, (0.952)
- Chi- Square is significant < 0.05
- ANOVA (F-test) is significant < 0.05

Deduction could be made from findings that the respondents' responses are significantly consistent and the strengths of relationships of the items considered are also significant

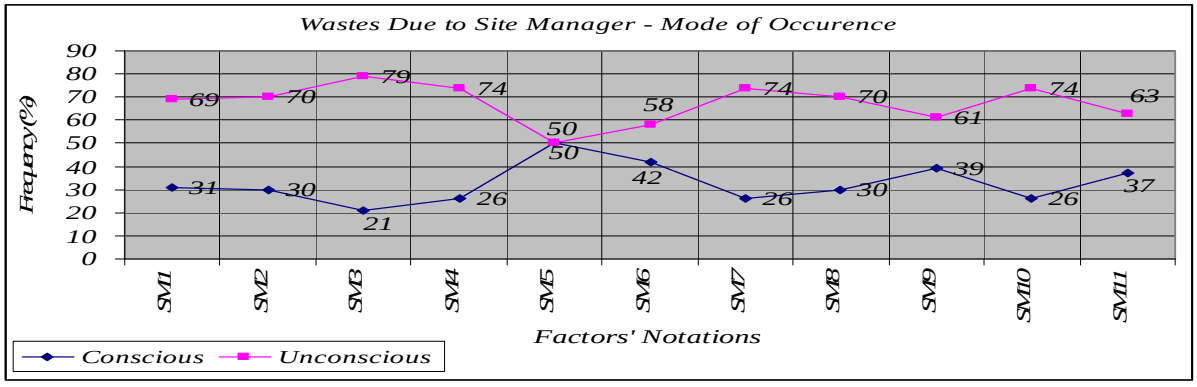


Figure 11: Modes of the Occurrence – Wastes due to Site Management

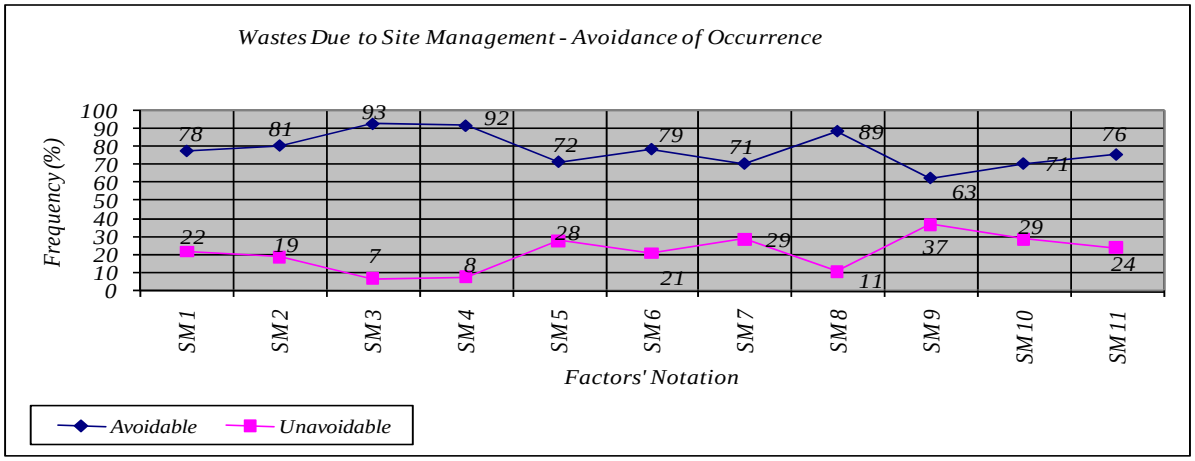


Figure 12: Avoidance of the Occurrence - wastes due to Site Management

- **Discussion of Findings from "Avoidance of Construction Resources Wastefulness", (ACRW) - Wastes due to Design Team Circumstances:** The causes of resources' wastes due to the Design team were evaluated. Five major factors were considered on frequency of occurrence; the consciousness of occurrence, and avoidance of the occurrence during construction production process. The findings obtained are presented in Tables 7 and 8; and, Figures 13 and 14.

  All the factors investigated were found to significantly causing resources wastefulness with percentage rates above average. In comparison, the effect of "variation approval delay" is the most significant factor, (67%), followed by "waiting time for approval of alterations" by client or design team, (63%).

  Deduction could be drawn from Table 5.35 and Figure 5.25 that 56% of the wastes due to Design Team occurs consciously, while 44% occurs unconsciously. However, the majority of these occurrences are significantly avoidable. Figure 5.26 indicates that none of the factors considered is unavoidable; the maximum unavoidable rate is 40% and the minimum avoidable rate is 60%.

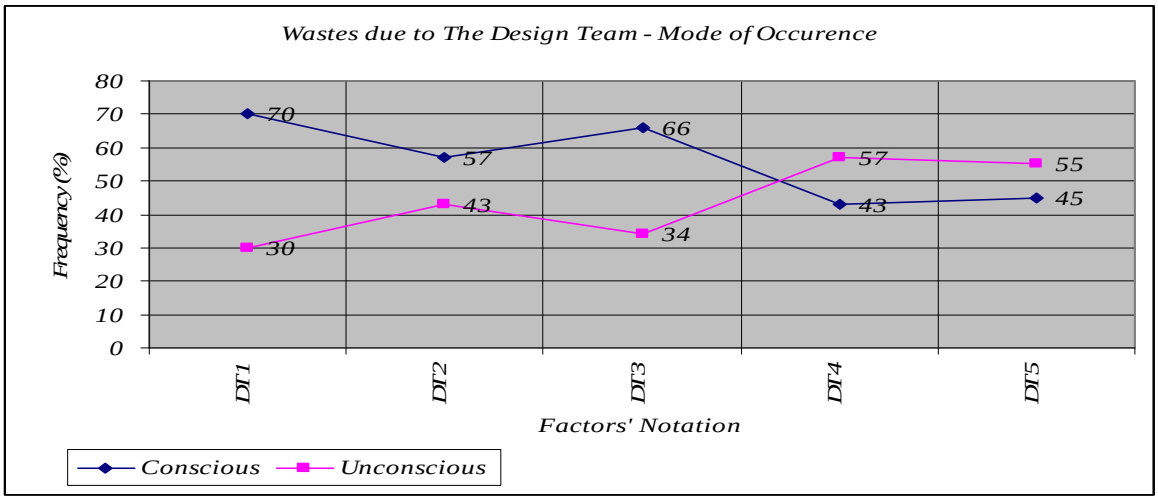
  From these results, there is the significant indication that resources' wastes due to design team are practically avoidable. This buttressed the quantitative research survey presented in Section 4.5, which indicates that "Architectural drawings and specifications" have maximum allowance for resources wastefulness. These facts are further investigated to ascertain the modalities of reducing or averting these predicaments towards enhancing efficient resources utilisation during production process. The findings are presented in Chapter Six.

Table 7: Frequency of Occurrence - Wastes due to the Design Team

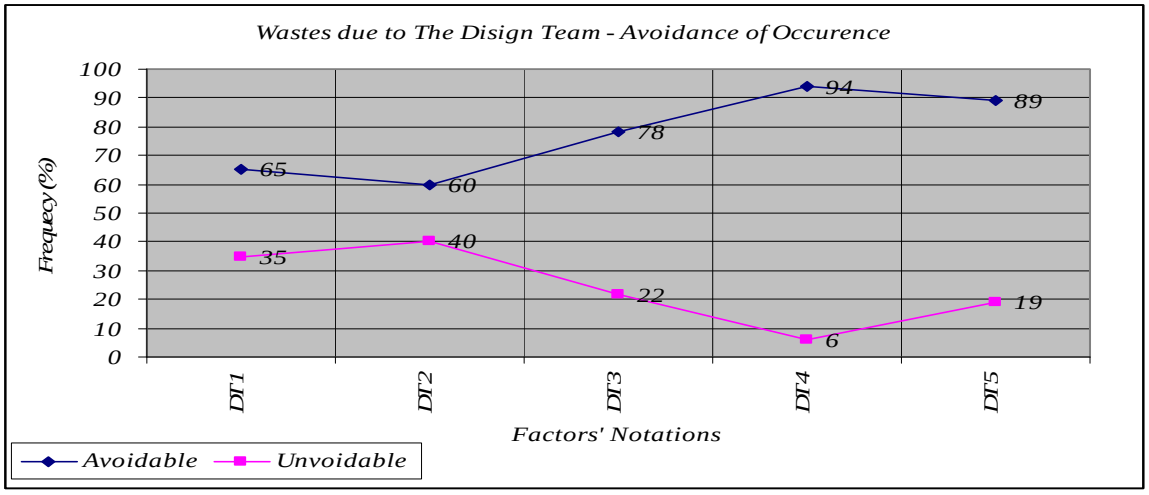
Wastes due to Design Team	Factors Notations	% Freq. of Occurrence
1) Variation. order delay that affect other work in progression	DT 1	67
2) Waiting time for alteration order.	DT 2	63
3) Delay in inspection to proceed to another stage of work.	DT 3	53
4) Communication gap between design and construction teams.	DT 4	60
5) Predominant meetings on variation, alterations and modifications, (time and manpower wastes).	DT 5	53

Table 8: Modes of Occurrence - Wastes due to the Design Team, (%)

Wastes due to Design Team	Con	Uncon	Av	Unav
Average of the Occurrences (%)	56	44	77	24



Figures13: Modes of Occurrence– Wastes due to the Design Team



Figures: 14: Avoidance of the Occurrence - Wastes due to the Design Team

The reliability and validity tests' statistics of all variables considered on wastes occurrence due to the design team are checked. The following facts are deduced:

- Corrected Item-Total Correlation: All items value > 0.3
- Cronbach's Alpha if Item Deleted: All items value < Total Cronbach's Alpha coefficient value, (0.937)
- Chi- Square significant < 0.05
- ANOVA (F-test) significant < 0.05

Deduction could be made that the respondents' responses are significantly consistent and the strengths of relationships of the items considered are also significant.

Additionally, the findings from the quantitative research survey assisted in composition of the in-depth interview research survey semi-structured, (guide) questions.

- ***Interview Research Study: Conscious and Unconscious Resources Wastefulness***

This interview research study enable the critical evaluations and assertions of several causes of conscious and unconscious resources wastefulness and made possible to establish how these problems could be significantly minimised or avoided.

- **Scenarios of conscious resources wastefulness:** The questions asked to ascertain causes of conscious resources wastefulness are:
  - What are the factors that often lead to conscious wastefulness of resources?
  - Why are resources being wasted consciously during the construction production process?

The identified factors that often lead to conscious wastefulness of resources are:

- Inadequate planning, occasionally caused by lack of sufficient time to plan before the project commences
- Scarcity of experience and skilled workers which results in utilisation of semi-skilled and unskilled workforce
- Over-procurement of labour due to the inability to ensure efficiency to meet the targeted delivery time, this overstaffing resulting in labour cost waste
- Unplanned redundancies and waiting time of plant and equipment
- Non standardisation of design dimensions with manufacturers' standards
- Safety factors in relation to time of delivery of the project by employing more resources than required
- Repetitive work due to poor workmanship
- Double handling due to resources positioning, trafficking and movement. Construction resources placed or stocked in inappropriate but available places that will require transportation to the place of usage often causes resources wastefulness
- Manpower redundancy and over procurement of labour due to an inability to ensure efficiency. That is, engaging excess manpower to execute the task in order to achieve the anticipated delivery time
- The environmental nature of the project site(s): several of the construction project sites are not environmentally pleasant; thus, many are times wastage is often being provided for probable unforeseen circumstances

The solutions to avoid or minimise conscious resources wastefulness are:

- Availability of sufficient time to plan the project before the project commences
- Re-planning during project execution, and to forecast and guide against probable occurrence of inefficient utilisation of resources
- Adequate monitoring and control of work materials, workers, and machinery
- Availability of resources when required or needed, delivered promptly
- Implicit design and precise specification are enhanced by considering manufacturers' standards dimensions

- **Issues of unconscious resources wastefulness:** In relation to unconscious resources wastefulness, the following questions were posed to the interviewees:
  - Based on the questionnaire survey findings, the majority of resources' wastes occur unconsciously, while these can largely be avoided. Kindly comment on these scenarios
  - What are the factors that lead to these scenarios?

  The following findings were obtained during the interview survey as significant causes of unconscious resources' wastes during production process:
  - Insufficient time to plan before the project commences
  - Human error and carelessness
  - Lack of adequate planning to foresee redundancy of resources. Several unconscious wastes are due to adequate planning of resources. Many a time, plant and equipment hired often remain redundant for periods of time
  - Complexity of design and inadequate specifications
  - Lack of site experience from previous job: a lack of experienced management or site participants on previous similar project(s)
  - Double handling due to Resources positioning, trafficking and movement, for example, materials placed or stocked in an available place that will require subsequent moving to place of usage

  The following facts were obtained, from the interview conducted, that will enhance the minimisation, or avoidance of unconscious resources wastefulness:
  - Proper planning and re-planning as the project progresses
  - Training of workers in awareness and benefits in resources effective utilisation. Workers need to be aware that the benefits are for the organisation and all site participants, and these benefits have to be clearly stated
  - Enhanced information dissemination and effective communication

- Challenge workers to be responsible for flimsy mistakes. Possibly, the workers need to be informed that they may be held responsible for obvious or careless resources wastefulness
- Monitoring of workers and plant efficiencies to avoid redundancy
- Adequate supervisions by experience/skilled superiors
- Availability of resources when required or needed, that is, prompt delivery
- Minimisation or avoidance of alteration and modification during work in progression through proper planning and implicit production information
- Minimisation or avoidance of human errors, through effective supervisions and monitoring, to avoid apparent or careless mistakes
- Adopting an effective supply-and-fix construction method, to reduce resources wastes, thus enhancing optimal utilisation of construction resources

5. SUMMARY AND TOPICAL ISSUES

This study establishes and ascertains how conscious and unconscious wastefulness can be avoided or minimised, and improvises how construction resources will be efficiently utilised during production process. As illustrated in Figure 15, this study identified and presented six wastes generation scenarios and areas of which there are significant needs for construction resources' wastes management towards efficient resources utilisation. The group factors are:

- resources' wastes due to materials inefficient utilisation
- resources' wastes that occurs due to manpower being not optimally utilised
- resources' wastes due to machine and equipment miss-management or under-utilisation
- resources' wastes that occur through production information
- resources' wastes incurred through the design team
- resources' wastes that resulted through site management ineffectiveness

It was found that the majority of the resources wastefulness in the construction industry occurs unconsciously, and could be avoided during the design stage before the production process commences. The results further indicate that majority of resources wastefulness are avoidable; based on the rationales that none of group avoidable rate is less than 73% and none of the group unavoidable rate is more than 27%, (Table 9).

Thus, there are needs for construction organisations to persistently strive towards achieving sustainability at every construction stage. Construction products make a vast contribution to everyone's quality of life. The products significantly alter the nature, and functions by which people perform activities.

Construction sustainability focuses on improving quality of life for all humans, without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely, (DTI, 2004). The need to harmonise environment, society and economy is not relatively new in human culture. What is considerably new is the articulation of construction sustainability concepts based on present innovations. The Department for Business Enterprise and Regulatory Reform, (BERR, 2007), affirmed that:

> *"Sustainability in construction is aimed to improve the resource efficiency, overall effectiveness, and social responsibility of the country's businesses which are involved in creating our built environment"*

Among the resources that are involved in creating the built environment are material, manpower and machinery resources, some of these resources are not only scarce, but are currently also expensive.

Egan, (1998) emphasise that; the construction industry needs to rethink the way resources are being used for its product delivery, and challenge the industry to explore various radical approaches in order to achieve dramatic increases in efficiency and quality that are both possible and necessary. However, as emphasise in Environmental Agency position statement, (2007),

> *"Promoting sustainable construction is difficult because of the industry's size and fragmentation"*

Irrespective of this considerable predicament, the immense contribution of the industry to the nation's national economy, (gross domestic product) and provision of valuable infrastructures makes the need for the construction industry to strive towards sustainability. Among the factors in achieving

the proclaimed construction sustainability objectives is the need for efficient minimisation of construction resource wastefulness.

6. CONCLUSION AND RECOMMENDATION

As sustainability is incontestable in the construction industry, optimal resources utilisation and resource waste management are significantly paramount, previous studies have identified various causes and suggested ways of improving resources utilisation. (Fapohunda et al, 2006, and Fapohunda et al, 2007). Complementing these previous studies, this paper identifies and establishes several factors that will significantly enhance sustainable construction resources utilisation, among which are: effective implementation of modern methods of construction, lean construction principles, and also effective involvement of clients towards reducing resources inefficiencies during construction production processes In addition, all construction clients and stakeholders need to be aware of the benefits that would be accrued through sustainable construction resources utilisation through minimisation or avoidance of conscious and unconscious resource wastefulness; which in consequence will directly or indirectly reduce construction cost, improve profit margins and client satisfaction.

The factors and proposals outlined in this paper will significantly enhance efficient utilisation of construction resources and perpetuate sustainable construction, if properly implemented.

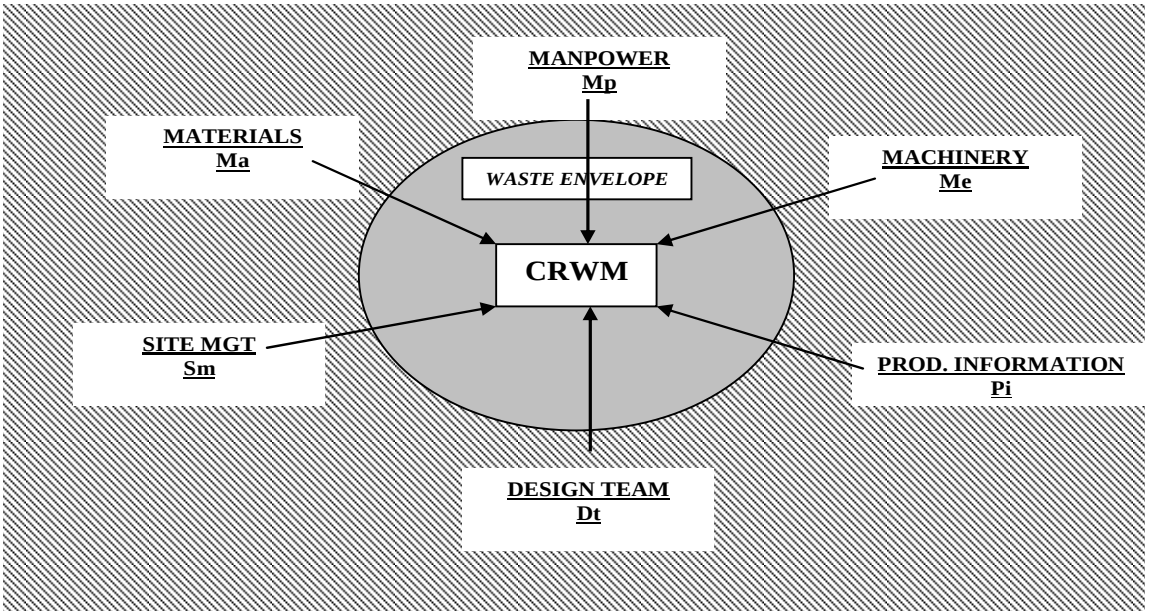


Figure 15: Factors towards Construction Resources' Wastes Management (CRWM)

Table 9: Summary of the Occurrence of Resources Wastefulness (Research Study Three)

Key: Frequency, (Freq); Conscious, (Con); Unconscious, (Uncon); Avoidable, (Av); Unavoidable, (Unav)

	Freq.	Con.	Uncon.	Av.	Unav
A) Wastes due to Materials	50	41	59	73	27
B) Wastes due to Labour	51	42	58	79	21
C) Wastes due to Plant and Equipment	52	45	56	83	18
D) Wastes due to Production Information	54	38	62	80	20
E) Wastes due to Site Management	53	33	67	79	21
F) Wastes due to Design Team	59	56	44	77	24
(Mean %)	53	43	58	79	22

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