Abstract

Competency-based measure is increasingly evident as an effective approach to tailoring training and development for organisational change and development. With design stage widely reckoned as being decisive for construction waste minimization, this study aims at identifying designers' competencies for designing out waste. Due to paucity of research into competency for construction waste mitigation, this study corroborates Verbal Protocol Analyses (VPA) with phenomenological research. Combining findings from the two methodological approaches, competencies for designing out waste are grouped into five categories, three of which are largely task related and two being contextual competencies. The study suggests that design task proficiency, low waste design skills and construction related knowledge are indispensable task competencies, while behavioural competence and inter-professional collaborative abilities are requisite contextual competencies for designing out waste.

In concurrence with task-contextual theory of job performance, personality variables and cognitive abilities are found to influence one another. This suggests that both task and contextual competencies are not only important, they are less mutually exclusive with respect to designing out waste. This study implies that apart from commitment and dedication of designers to waste minimization, design and firm practices are expected to be adapted to the industry's standard. Basis for training needs of design professionals as well as redeployment criterion are further elaborated in the paper. By enhancing competencies identified in this study, construction waste would not only be significantly designed out, adequate cost saving could be made as a result of waste reduction.

Keywords: Competency; Construction waste; Design management; Task-contextual model; Protocol analysis

Introduction

The construction industry is the largest contributor of waste to landfill sites (Ibrahim et al, 2010), and it consumes up to 50% of mineral resources excavated from nature (Anink et al, 1996). The industry also generates about 33% of CO_2 present in the atmosphere (Baek et al., 2013). With its growing rate of materials consumption and waste generation, the industry has remained a major target for global sustainability agenda (Anderson et al, 2002), and its sustainability strongly depends on its ability to reduce its own waste (Lau et al., 2008; Yuan, 2013). In addition, a UK government constituted study suggests that reducing construction waste by just 5% could result in an annual cost savings of about £130million (BRE, 2003). Consequently, significant waste management research have been carried out since around 1970s until date. These have led to identification of various waste causative factors, and development of several waste mitigation and management strategies, among others. Cornick (1991) posit that a large percentage of construction problems are due to decisions made at design stage of project delivery process. It is therefore recognised as a decisive stage with multiple implications on project outcome. In line with this, evidence suggests that waste could be significantly reduced by taking waste preventive measures at the design stage (cf. Osmani et al., 2008; Faniran and Caban, 1998; Ekanayake and Ofori, 2004). This suggests the need to address construction waste from design perspective.

Despite the claim that waste efficient designs are capable of halving construction waste to landfill (WRAP, 2009), the proportion of waste generated by the industry increases. Osmani et al. (2008) assert that lack of adequate training and competencies by design professionals is a leading cause of waste in construction projects. While studying impediments to recycling and waste diversion from landfill, Oyedele et al. (2014) argue that designers rarely specify recycled products due to their insufficient knowledge of the products and its associated quality and technology. Wang et al. (2014) also recognise designers' lack of experience and competencies as a leading cause of construction waste. All these suggest that competencies and effectiveness of design professionals are indispensable to reducing waste intensiveness of the construction industry. Albeit the consistency of these claims and increasing understanding of the impacts of design on waste generation, the nature of training and competency required for designing out waste remain unaddressed.

In recent times however, the relationship between competencies and achievement of desired goals has become more noticeable in many project-based organisations within the construction industry (cf. Dainty et al., 2005; Zhang et al., 2013, Hardison et al., 2014, Lampel, 2001). Ahadzie et al. (2008) argue that competency-based measure is indispensable to achieving desired professional development within the construction industry. While much has been done to define skills, tools and competencies required by other actors within the construction industry, – contractors and project managers for example – designers' competency remains generally elusive (Alzahrani and Emsley, 2013; Dainty et al., 2004, 2005a; Ahadzie et al., 2014; Ling, 2003). Even though, substantial research has been carried out to determine factors contributing to waste generation as well as impacts of design on waste output (cf Osmani et al., 2008; Formoso et al., 2002; Faniran and Caban, 1998), analysis from competency perspective is generally lacking. Irrespective of the consensus that designers are the most important driver of low waste construction projects, there is paucity of literature on design skills, competencies and training required for driving waste efficient projects.

Conforming to the theoretical position that, with enough agreement, experts are able to identify critical incidents and factors capable of determining their job/task effectiveness (Motowildo et al., 1997; Flanagan, 1954), this study seeks to determine competencies required of designers in designing out construction waste. The study fulfils its aim through a number of research objectives, which are:

(1) To identify design knowledge, habits and skills requisite for designing out waste.

(2) To map out and explain designers' waste minimization competencies with respect to task and contextual abilities.

(3) To determine training needs and requirements for reducing construction waste through design.

Based on epistemological perspective that a poorly understood or entirely new concept could be well studied by suspending all preconditions (Holloway and Wheeler, 1996; Van Manen, 1990), phenomenological approach is used in the study. Apart from focus group discussions, a combination of concurrent and retrospective verbal protocol analyses, otherwise known as "think aloud protocol," were used to elicit experts' opinion (cf. Ericsson and Simon, 1993; McGuinness and Ross, 2003; Ericsson, 2006). Result of the study will enhance development of training programmes capable of improving skills and competencies of design professionals in designing out waste. It will also enable the professionals in understanding competencies that are required to be strengthened in a bid to design low waste projects. By acquiring the right set of competencies, construction waste would not only be reduced, significant cost saving could be made as a result of waste reduction (BRE, 2003).

To posit the study within a suitable theoretical framework, the importance of competency-based approach is elaborated before describing the concept of competency and evaluating relevant competency models. The methodology used in the study, including data collection and analytical procedures, are then justified and described. This is then followed by reportage and discussion of the finding after which the study is culminated with a summary of the issues identified. Theoretical and practical implications of the study as well as areas for further research are also presented.

Strategic importance of competency-based approach

In recent years, there has been a growing importance of the roles of competency-based training in many industries and sectors. In response to the organisational shifts from functional competencies, which measures employees' performance against predetermined standards, to competency-based measures, research is rife on the concept of superior performance that underlies the competency-based recruitment and training. Rather than behavioural models, the motive for introducing competency-based measure to organisations is to enable HR managers to identify skill sets required for effective job performance, thereby tailoring job recruitment and on the job learning towards them (Gangani et al., 2006). According to Dainty et al. (2004), attention is being paid to competency-based approach as it enhances employees' development and reward towards engendering their competitive capabilities. In addition, the measure has become a strategic tool for stimulating staff training needs, developing effective job description and facilitating adequate decision-making concerning employees (Ahadzie et al., 2008). It has also become an effective means of establishing and tailoring training needs towards improving employees' efficiency.

In line with this growing awareness, acquisition of relevant skills, knowledge and competencies have become a significant concern in the construction industry (Egbu, 1999). It has been argued that competency-based measure is important for achieving effective performance with respect to time, cost and quality, which are the common measures for evaluating project success (Takey and de Carvalho, 2015). As such, studies are rife concerning competencies required for effectiveness of construction projects (Cf. Egbu, 1999; Ahadzie et al., 2008; Dainty et al., 2004; Hardison et al., 2014; Lampel, 2001). For instance, Rwelamila (2007) investigated the skill sets and competencies needed for effective project management in public sector organisations. The study resulted in development of framework for re-assessing and re-organising public project management structure. Dainty et al. (2004) identified core competencies required for effective project management. The study employed McBer competency framework and concluded that factors relating to composure and team leadership are requisite to effective performance as project managers. A similar study by Edum-Fotwe and McCffer (2000) also identified sets of primary and secondary skill sets for effective project management.

A study carried out to determine competencies required for refurbishment work stressed the need for more competencies in conflict management, forecasting and planning, decision-making and team building than as required for general project management (Egbu, 1999). Apart from general competencies for construction activities, studies have also been carried out to investigate competencies required for different aspects, stages or types of projects. For instance, Hardison et al. (2014) investigate competencies for effective site safety; Ahadzie et al. (2014) explore competencies for effective project management at design phase, while Hwang and Ng (2013) determine project management competencies for green construction. These sets of studies identified measures for achieving effective performance at targeted stages or aspects of building delivery processes. It was notably established that both job related skills and behavioural factors are important for effective performance at the managerial roles in the construction industry. Results of the studies pointed out to the effectiveness of competency-based research in determining measures for identifying training needs as well as strategies for improving employees' performance on specific or overall aspects of their jobs.

Despite the strategic importance of competency-based measures throughout all stages of project delivery process, construction research has concentrated on competency required during the construction stages, with most studies addressing the competence of project managers. Notwithstanding the understanding that designers drive activities at other stages of project delivery process (Lawson, 2006), competency required for effective design remain unaddressed. Although inadequate knowledge of strategies for waste prevention has been identified as a major cause of construction waste generation (Osmani et al., 2008; Oyedele et al., 2014), there has been no sufficient attempt to determine competencies for effective waste mitigation at design, procurement and construction stages of project delivery process. Albeit the need for designers to drive low waste projects, there is paucity of literature on design skills, competencies and training required for designing out construction waste. Worst still, the generic nature of the UK National Occupational Standards, with respect to designers, made it difficult to understand the particular competencies that could assist in designing out waste. Thus, it is important to employ relevant competency-based framework to determine competencies and skillsets required for designing out waste generated by construction activities.

Theoretical Framework for the Study

Due to diverse philosophical approaches used in its studies, the term competency has been used to mean different but similar things across several studies (Zemke, 1982). According to Spencer and Spencer (1993), competency refers to a set of skills, abilities and individual characteristics that have causative influence on effective job performance. Competency is taken as “a descriptive tool that identifies the skill, knowledge, personal characteristics and behaviour needed to effectively perform a role in the organisation and help the business meet its strategic objectives” (Lucia and Lespinger, 1999, p.5). Holtkamp et al. (2015) also defined competency as a set of abilities, skills and attitudes required for solving problem in a particular context. This description strongly suggests that competency is context dependent, and it could vary from one job role to another. It covers observable and testable abilities such as skills and knowledge, as well as those that are less obvious such as personal characteristics and qualities (Vazirani, 2010).

Suggesting competency as an effective measure for predicting workplace success, McClelland (1973) is credited with the notion of competency-based measures rather than using IQ test as a yardstick for recruitment and training (Getha-Taylor, 2008). Since McClelland’s work, competency has attracted significant research efforts leading to development of various forms of competency models. According to Dubois (1988), competency models are in four categories, which are organisational, occupational, job/functional/role and leadership competency models. This is in line with the claims of Spencer and Spencer (1993) who argue that competency models could be developed for specific job role, organisation, job groups, occupation or industry.

Built through a process of continuous development, organisational competency addresses the capability required for achieving business competitive advantage. Resource based view

(Wernerfelt, 1984), core competency theory (Prahalad and Hamel, 1990), and dynamic capability theory (Teece et al. 1997) are examples of competency models in this perspective. Occupational competency models, such as OCM by Shaw and Polatajko (2002), cover critical skills and capacity required for broad occupational areas such as engineering and medicine among others. Leadership competency models address set of competencies required of leaders to articulate coherent vision and translate them into reality by effectively directing and managing employees towards achieving organisational goals. Adair's action centred leadership model (Adair, 1973) and Hersey-Blenchard model of leadership (Hersey et al., 1988) are example of models developed in this perspective. Job competency models, on the other hand, seek to capture a set of skill that are specific to a job role or work unit within an organisation. Examples of this include task-contextual model (Motowildo et al., 1997), Boyatzis' model of effective job performance (Boyatzis, 1982) and Icerberg Model (Spencer and Spencer, 1993), all of which seek to develop basic foundation for recruiting suitable employees and developing training for achieving effective performance.

The overall occupational role of a designer is not to design out waste, it is rather a functional role or work unit. As such, job or functional competency models such as task-contextual, Iceberg and Boyatzis' model are suitable for identifying and developing skill sets and competencies required for designing out waste. Built on McClelland's Mcber job competency framework, Boyatzis (1982) argue that competency is a mix of different measures such as personal traits, motivation, knowledge and skill, all of which could be evident in job action, job performance, behaviour and relationship with others. While skills and knowledge are the generic competencies that a person brings to a job role, social roles and behaviour could be categorised as competence if they directly influence job performance.

Just like an Iceberg that have about one-ninth of its volume above water, Iceberg theory posits that competency is partly determined by visible features, while hidden features have greater impacts on job competency. Spencer and Spencer (1993) argue that knowledge and skill are at the tip of competency iceberg, while self-concept, trait and motives are deeper down in the hidden part of the iceberg. Although the features at the lower part are difficult to measure, the model posits that they contribute about 80% of job competency, while skill and knowledge contribute the rest. Skill and knowledge refer to observable abilities required for a job position. Self-concept, trait and motives, on the other hand, are more personal, attitudinal and could be likened to what Motowildo et al. (1997) refer to as contextual competencies.

Drawing on the strengths and weaknesses of these sets of job competency theories, task-contextual theory is adopted for this study.

Originally proposed by Motowildo et al. (1997), task-contextual competency model posit that job performance and effectiveness is determined by individual differences in task and contextual abilities, each of which is made of knowledge, skills and work habits. Whereas task competencies are individual's proficiency in activities contributing to the technical core of an organisation or job role, contextual competencies do not constitute the technical core, but support organisational, psychological and social environment within which its goals are pursued (Motowildo et al., 1997). Task performance is the technical core, which is done by executing technical requirements of the job. Contextual competencies are personality, behaviour and motivation related, and it is more discretionary or supportive in nature. It also involves ability to cooperate, work with, or assist others towards achieving collective organisational goals. The notion of teamwork, interpersonal facilitation and adherence to organisational goal are all contextual (Ahadzie et al., 2014).

Task-contextual theory suggests that a good approach to determining competencies required for a job role is to understand task and contextual requirements of the job. This would result into six categories of performance, which are task skill, task knowledge, task habit, contextual skill, contextual knowledge and contextual habits. In addition, the theory is divided into cognitive ability, which has more to do with task performance, and personality variable, which is more related to contextual performance. The theory however predicts that personality variables might have effects on task performance, while cognitive ability could also be related to contextual performance. In particular, personality traits tend to affect task habit, as cognitive ability could affect contextual knowledge. Thus, based on experts' opinion and protocol analyses, this study maps out and discusses competencies for designing out waste in line with task contextual model. Figure 1 provides a theoretical framework for the study.

Figure 1: Theoretical framework for the study

Methodology

Albeit widely recognised impacts of design stage on construction waste, there is lack of literature on the skill sets needed for designing out waste. According to Crotty (1998), in order to explore a new concept or a widely neglected area, exploratory research is a suitable strategy of enquiry. As such, this study employs focus group discussions and Verbal Protocol Analysis (VPA) as exploratory approaches to data collection. Figure –2 depicts methodological approaches to the study. These approaches avail the researchers an opportunity to interpret participant's action and experience as it is performed or related.

Figure 2: Methodological approaches to the study

Verbal Protocol Analysis (VPA)

VPA, otherwise known as "Think Aloud Protocol", is a method for collecting and analysing verbalised thought during cognitive processes, such as problem solving, decision making, computer interaction and mental calculation, among others (McGuinness and Ross, 2003). It involves a process whereby participants are asked to verbalise their thoughts as they perform or complete tasks under investigation. While concurrent VPA involves verbalisation of thoughts during the process of completing the task, retrospective protocol involves a process whereby participants are asked to relate their thoughts after the task is completed. Outline in-depth by Ericsson and Simon (1993), VPA is continuously gaining popularity in design research (cf. Gero and Mc Neill, 1998; Perry and Krippendorff, 2013).

To make for error that may arise as a result of difficulty in putting every thought into words within limited period (Ryan and Haslegrave, 2007), this study corroborates concurrent VPA with retrospective VPA. The sampling procedure follows purposeful and convenience technique as the participants were selected based on researchers' network of contact within the UK design and construction firms. However, invitation was only extended to design firms within the best 100 firms, based on 2014 ranking by the building.co.uk. An invitation letter that details the purpose of the study was sent to 24 design firms within the UK, out of which eight positive responses were received. A telephone follow up also resulted in one additional response. However, decision was made to limit the number of respondents to five, as each verbal protocol encounter usually generate voluminous data, in addition to lengthy period of time and financial requirements (McGuinness and Ross, 2003). This is in line with the position that an individual subject with adequate expertise might be sufficient in an exploratory VPA study (Trickett and Trafton, 2007). In all, five expert designers, including three architects, one civil/structural engineer and one M&E professional, having experience ranging from 15 to 30 years, were the subjects of the VPA.

Each of the participants was told to verbalise his/her thoughts during one-week design exercise, which was recorded with their permissions. To capture some thoughts that might be difficult to verbalise during the process, a further 30 minutes retrospective protocol analysis followed each day of data collection with each participant. The retrospective process also helped in scaling down the identified protocols to those that are done for waste preventive purposes. Based on VPA procedure recommended by Ericsson and Simon (1993), the recorded voice data were transcribed, segmented and coded into different skill sets and competencies required for designing out waste. For the purpose of validity, identified competencies were sent back to the participants for clarification and confirmation.

Focus Group Discussions

Focus group discussions were used to elicit broader experts' opinions on competencies required for delivering waste efficient design. This data collection technique was used as it does not only assist in gaining in-depth understanding of the concept, but also allows participants to build on each other's opinion throughout the course of the encounter (Wimpenny and Gass, 2000). The data collection technique therefore avail the opportunity of establishing common understanding of the research participants in each of the discussions. In line with Merriam's (1998) position that the use of purposive sampling ensures effective exploration of subjects in qualitative enquiry, this study employs purposive sampling technique. Apart from the designers, who are central to the enquiry, other parties involved in building delivery processes were also invited. As such, the selection criteria were based on job position, years of experience within the ACE industry and involvement in waste preventive or management activities. Contractors and project managers were purposely included in the discussions as evidence shows that they usually shift the blame to the designers (Osmani et al., 2008; Oyedele et al., 2014). Having them together in a focus group discussion assisted in critical examination of intersubjective opinions, thereby arriving at consensual opinion.

After identifying suitable participants through a list of top 100 architecture and construction firms within the UK, the participants were reached based on the research team's network of contacts within the UK construction industry. A selection technique that takes after Akintoye et al. (1998), Hodgson et al. (2011) and Oyedele (2013). Participants were earlier intimated about the nature and scope of the focus group discussions prior to the scheduled meeting. In all, the study involved four focus group discussions with designers, contractors and project managers with none of them having less than 10 years of experience within the industry. Table –1 shows categories and number of participants in each of the discussions. A total of 23 experts participated in the four focus group discussions, making the findings well informed, as participants between five and 25 are adequate for a typical exploratory research (Creswell, 2013). For the purpose of triangulation and holistic exploration, none of the participants in the VPA was involved in the focus group discussions. This gives opportunity to get opinions from other experts than those involved in the think aloud protocol.

The discussions were moderated by two members of the research team, with each of the discussions spanning between 75 and 90 minutes. The recorded interview was converted into written scripts, which was then analysed to establish competencies for designing out waste. This was achieved through qualitative analysis of the focus group transcripts with the aid of Atlas-ti version-7. Owing to the need to go beyond word counting, content driven thematic analysis was used for data analysis as it considers both explicit and implicit ideas within the data (Braun and Clarke, 2006). As such, the analytic process involved data familiarisation within an Atlas-ti Hermeneutic Unit, generation of codes, search for themes, review of themes and definition of themes as suggested by Braun and Clarke (2006).

Table 1*:* Overview of the focus group discussions and the participants

Coding Scheme and Categorization

The coding scheme and final categorisation of identified competencies were based on dominant themes that emanated from individual and combined analysis of data from all focus group discussions and Verbal Protocol Analysis. Basically, the coding scheme was used to identify individual competencies for designing out waste as well as the broad categories of competencies required for achieving low waste design. Generation of initial codes was facilitated through "word cruncher" facility provided by Atlas-ti qualitative data analysis tool. Apart from a thorough reading of the transcribed data, the word cruncher enhance a general overview of commonly used words that existed in the data. As such, the study employed a data driven coding technique, which ensure a holistic processing of all themes evolving from the data (Braun and Clarke, 2006).

In line with Gu and London (2010), coding system in this analytical process was enhanced by the use of five broad categories, which are discussions, type, context, level and codes/keywords. Each of the broad categories are briefly explained below:

The "discussion" identify the particular focus group discussion or VPA where the factor or competency was raised.

The "type" category was used to classify the purpose of the statement from which the theme/factor emanated. This was to highlight whether the identify theme falls into such grouping as strategy, opinion/viewpoint or criticism/concern. The "type" classification avail the researcher the opportunity of highlighting whether the identified competency refers to a known requisite for designing out waste or a lacked competency that usually engender waste generation.

The "context" was used to signify the circumstance through which the theme emanated. It determined whether the identified theme was initiated, a reply to issues raised, or a follow up to an ongoing discussion.

The "level" category itemise whether the identify factor is a key theme or a sub-theme contributing to the key theme.

The "codes/keyword" marks the particular words that led to identification of the factor, competencies/sub-theme or key theme/key competencies.

To demonstrate the use of the coding scheme and categories, Table 2 shows example of coded segment. As an illustration, line 1 of the Table 2 shows a viewpoint initiated by a participant from Focus Group discussion 2. The keyword that resulted into the quote was “error”, and the quote formed a sub-theme of a main theme, which is “task proficiency”. It resulted into “ability to produce error free designs” as a competency for designing out waste.

After a thorough generation of codes and their corresponding quotations, relevant quotations were used to establish both implicit and explicit competencies that were pointed out by the participants. Similar themes/competencies were then mapped together to form broader themes. The themes explain more holistic factors and competencies that are generated by combining very similar factors emanating from the data. For instance, knowledge of real life site layout and knowledge of construction processes are integral part of a larger theme referred to as “construction related knowledge”.

In all, the identified set of themes/factors were categorised into five key themes, which defines the competencies required for designing out waste. These are task proficiency, low waste design skill, construction related knowledge, behavioural competence and inter-professional collaborative competence. Table–3 combines triangulated findings from the two methodological approaches. The task competencies encompass the set of themes/codes that are related to day-to-day job responsibilities of designers; competencies required for low waste design technology are categorised as low waste design skills, while knowledge of construction site activities are categorised under construction related knowledge. In line with Motowildo et al. (1997), behavioural competency encompass all factors related to self-conviction and disposition to waste mitigation, while inter-professional competency aggregates all competencies required for effective collaboration with other parties involved in building delivery process. Each of the key competencies are further discussed and buttressed by quotations from the data as recommended by Creswell (2013). Based on the use of Task-contextual model as the underlying theoretical framework for the study, Figure –3 mapped the identified categories of competencies with elements of the theory as originally illustrated by Motowildo et al. (1997).

Table 3: Competencies for designing out waste in construction projects

Figure 3: Concurrence of Task-Contextual Theory with the Identified Set of Competencies

Discussions

As shown in Table –3, experts opined that core competencies for designing out waste in construction projects are in five major categories, ranging from job demand skills and knowledge to individual factors and inter-personal relationship. Based on the findings of this study, Figure –4 depicts framework of competency for designing out waste in construction project. The component parts of the framework, which are the identified core competencies are discussed in this section.

Figure 4: Competency based model for designing out construction waste

Task proficiency

This study suggests that design task competencies are indispensable to achieving low waste construction projects. This buttresses findings of earlier studies aiming at identifying design factors with causative influence on construction waste. For instance, design error, poor detailing and inadequate specification are known causes of construction waste (Faniran and Caban, 1998; Formoso et al., 2002). Strong indication emerged from VPAs and focus group discussions that the extent to which a designer is capable of considering basic design quality indicators would determine waste induced by design. These sets of design quality indicators include design functionality, detailing, specification as well as the quality of its documentation (Gann et al., 2003; Andi and Minato, 2003). The participants stressed that:

> *"…for construction waste to be prevented through design, the designers must be able to prevent all forms of design and detailing errors..."*

> *"Particular attentions need to be paid to the issue of specification….designers must be versed enough to specify materials that would just be adequate…what we usually experience is that materials are either under-specified or over-specified, and it always result in leftovers and waste…"*

As illegible or incorrectly detailed design leads to construction waste, ability to produce error free design, correct materials specification and coherent documentation, using conventional vocabulary, are key competencies for designing out waste.

In addition, it was raised that competency of a designer in designing out waste is determined by the extent to which constructability thinking comes into his/her thought process. A focus group participant argued that:

> *"Some designers don't just understand issues around constructability...they are mostly fascinated by aesthetics and shapes…"*

Constructability of a design refers to the extent to which it facilitates ease of construction (Lam et al., 2012). A construction project tends to be waste intensive if buildability/constructability, as basic design quality, is not thoroughly considered in the design process (Yuan, 2013b). It results in project delay, cost overrun and design change, which is a major cause of waste (Yeheyis et al., 2013). As such, improving designers' constructability thinking is a measure for improving waste effectiveness of construction projects.

Corroborating findings from the focus group discussions, design protocol analyses suggests that a good yardstick that determines competency for designing out waste is the extent to which a designer considers the proposed site. During the think aloud process, attention was paid to the proposed site as well as how existing facilities would be integrated into the new design. This reinforces the assertions that ability to integrate design with site topography and consider reusable elements onsite determines competency for designing out waste. It was stressed that:

> *"If a designer lacks knowledge of what and what are reusable onsite, they will fail to integrate them into their designs….."*

> *"Knowledge of site topography…and how to produce an organic design is important for reducing excavation waste…design should flow with the natural topography with minimal level cuts…."*

These assertions aligns with earlier suggestion that designers are not only to design in response to site topography (WRAP, 2009), but are also expected to identify and integrate reusable elements into design (Begum et al., 2009). This could range from materials from previous buildings, in case of redeveloped site, to excavation materials where new sites are being developed (Del Río Merino et al., 2009). Thus, in addition to adequate technical and cognitive design skills, constructability thinking and ability to design in conformity with site are basic task competencies required for designing out construction waste.

Low Waste Design Skills

Certain design techniques and skills are potentially waste effective. Improving proficiency of designers in such technique are agenda for Continuous Professional Development (CPD) with respect to waste management. Consequently, designers' competency for designing out waste is directly related to their proficiency in the low waste design skills and techniques. A number of such skills and techniques illuminated by this study include effective coordination of elements' and components' dimensions, design for flexibility and adaptability, and design for deconstruction. Proficiency in these sets of skills and techniques determines the level of competency with which a designer could drive low waste project. The think aloud protocol suggests that expert designers have series of design thinking while preparing their design. For instance, one of the designers echoed that:

> *"…if I make this to be 2.4, there will be no ceiling offcut…"*

This buttresses the claim that ability of designers in ensuring dimensional coordination could significantly reduce materials offcuts and its subsequent waste generation (Ajayi et al., 2015). The focus group participants also opined that:

> *"Offcut waste could be reduced if designers are aware of standard materials supply sizes and they design in response to that"*.

> *"Designers should also understand the kind of materials, assembly, joint… and construction techniques that could enhance end of life deconstruction….If all these are achieved, demolition wastes could be prevented"*.

Meanwhile, Crawshaw (1976) points out that reworks and its associated waste and cost overrun is as a result of ineffective coordination of design. Similarly, Yuan (2013b) and Mckechnie and Brown (2007) opined that substantial construction waste could be reduced by designing buildings in response to future change and adaptation. Oyedele et al. (2013) also suggest that design for disassembly and subsequent production of deconstruction plan is a means of reducing waste intensiveness of construction industry. These set of studies concur with this study, which posits that competency for designing out waste could be improved by learning skillsets required for the low waste design techniques.

Strong indication emerged from this study that competency for designing out waste could be tested by evaluating level of designers' understanding of certain design criteria. These include knowledge of secondary materials, standardization of design to standard materials supply and ability to drive low waste technology. This is as echoed that:

> *"Designers determines what we have on site…if they are able to design in response to how materials are usually supplied…for instance at an increment of .3m…waste would be significantly reduced"*

> *"Although some people may argue that use of secondary materials is not a waste efficient technique…but it is. Designers should be aware of quality grades of secondary materials and specify them accordingly"*.

Balance theory for recycling suggests that by using secondary materials equivalent of waste generated, landfill sites would be freed (Wong and Yip, 2002). Notwithstanding this, Oyedele et al. (2014) found that recycled materials is less acceptable in construction industry as designers lack adequate awareness of its durability, market availability and correct specification. In addition, design in conformity with market supplies of materials will prevent waste due to offcuts, which contributes a large proportion of construction waste (Formoso et al., 2002). As such, adequate knowledge of materials standard supplies and secondary materials, as well as their efficient specifications are important competencies for driving low waste culture within the construction industry.

In conformity with the claim that the use of precast elements could reduce construction waste by up to 84% (Jaillon et al., 2009), this study suggests that possessing skills required for offsite and preassembled components are requisite to designing out waste. The participants opined that:

"At this modern age, a key competency for preventing waste is designers' ability to design, lead and motivate precast technologies… and other modern methods of construction".

Although higher cost of precast system, than in-situ, means that premium is always paid for the technology, it supports adaptability, deconstruction and reuse of building components. While the respondents concur that few projects will adopt prefabrication technology, they however opined that ability to effectively design for preassembled components, when required, is part of competencies for designing out waste.

Construction Related Knowledge

Causative influence of design stage on construction outcome is well established across literatures (Cornick, 1991). The extent to which designers consider actual construction process would determine the ease with which construction is carried out. In line with this, the study suggests that designers' proficiency in construction related knowledge is a measure of their competencies in designing out waste. The participants suggest that:

"Knowledge of construction is very important for designers......if a designer have construction related knowledge, it will improve the way he designs out waste….."

"A designer that is aware of real site layout and how construction activities are carried out in a site setting will be able to prevent some forms of waste".

In line with this finding, Alshboul and Ghazaleh (2014) suggest that knowledge of construction process and sequence would assist designers in preventing certain forms of error that could result in waste. For instance, adequate knowledge of which of wall tiles and floor rendering comes first could reduce offcuts or over ordering of tiling materials. In the same vein, understanding whether ceiling materials is fitted before wall rendering could assist in saving cost and preventing materials wastage. By understanding how construction site layout and activities are carried out, designers would be able to design in resonance with subsequent businesses.

Apart from awareness of construction operation sequence and real site activities, adequate knowledge of construction materials is required for designing out waste. The experts posit that:

> *"Knowledge of materials quality and durability are essential to correct specification and waste prevention"*

This corroborates the position of Dainty and Brooke (2004) who argued that large percentage of building renovation waste is due to use of less durable materials, which requires incessant replacement. Thus, designers are not only expected to be versed in standard materials supply and specification, their knowledge of materials quality and suitability for purpose would enhance competency for preventing waste.

Behavioural Competence

Likelihood of designing out construction waste is not only determined by cognitive ability and knowledge of designers, behavioural competence and personal commitment is the underlying factors that determine whether the skill and knowledge would be applied. These sets of behavioural competencies have also been referred to as self-competence. Harter (1982) refers to self-competence as one's perceived ability and belief with respect to a particular task. With respect to designing out waste, this study refers to self-competence as self-awareness and concept, ability, motivation, attitude and dedication to waste minimization. In order to design out waste, this study finds that designers should be versed and dedicated to understanding waste causative influence of design in addition to their knowledge of design action that result in waste. This according to the focus group discussion and verbal protocol are fundamental to designing out waste. It was stressed that:

> *"Some designers are still unaware of their roles in construction waste prevention…this is where the issue start. There is need for more awareness, commitment and dedication on the part of designers…. Because, they drive the whole building process".*

> *"Just as most contractors understand waste as an issue to be tackled, the designers should also change their disposition to waste*

management…..understanding impacts of waste on cost and environment could drive designers' dedication to designing out waste."

While investigating architects' perspectives to waste reduction by design, Osmani et al. (2008) make a similar claim that understanding underlying causes and origin of waste is a requisite knowledge for reducing waste by design.

Asides basic understanding of design causes of waste, commitment on the part of designers determines attitudes to waste management. To raise self or behavioural competence for designing out waste, more dedication is needed from designers, some of who believe that waste is only site induced, and that they have no professional responsibility for tackling it (Osmani, 2013). This commitment could be demonstrated by setting waste minimization as priority, avoiding known waste inducing activities, engagement in training and development, among others (Lu and Yuan, 2010; Mckechnie and Brown, 2007). Thus, task and contextual habits that support waste minimization practices are important competencies for designing out waste.

Inter-professional Collaborative Competencies

The construction industry is a highly fragmented project-based industry that seeks to meet demands of its customers within limited budget, resources and period. The industry is large, complex and diverse, and covers a wide range of micro, small, medium sized and large businesses that are united by their output. Corroborating the need for inter-professional collaborative competencies, Osmani (2013) opines that although zero waste targets was debated for construction industry, concerns regarding the industry's fragmentation and poor collaboration prevents its implementation. In line with this, Canadian National Inter-Professional Competency Framework (2010) suggests that achieving optimal outcome in a multi-professional engagement requires effective collaboration and role awareness between parties involved. All these point to the importance of inter-professional competencies in such a highly fragmented and multi-party settings like the construction industry.

Ability to coordinate design from various trades including architecture, M&E, and structural engineering is an important competency required of design managers, as it will assist in early detection and mitigation of design clash before construction. This aligns with argument by

Crashaw (1976) who points out that poor coordination of designs is a major cause of waste and rework. In order to avoid make-do waste which occurs as a result of poor communication between design team (Koskela, 2004), this study suggests that designers are not only required to understand team functioning and role responsibility, they are expected to have competencies for effective communication within and across trades. The focus group participants viewed that:

> *"You may have a well-coordinated design as an architect or MEP, but if there is lack of adequate knowledge of coordinating design from all disciplines, you might end up in design clash, reworks and waste."*
>
> *Inter-professional collaboration is very important in the construction industry. Apart from job-based competencies, everyone must be aware of roles of others and how to communicate effectively within the team.....this will prevent likely conflict, design clash, errors…and so on that could result into waste."*

Apart from competencies required for managing project team works, interpersonal management, inter-professional conflict management skill and collaborative competencies are required for minimizing waste in construction projects. This means that other than proficiency in design task, contextual performance of designers is a good measure of their competency for designing out waste.

Practical Implication of the Findings

A review of competencies and competency models by Vazirani (2010) suggests that competency related studies are done for one or more of seven purposes. In most cases however, competencies are studied to determine recruitment criteria or as an agenda for training and development (Sanghi, 2007). Where competencies are studied with respect to overall job requirements, it could possibly serve the two purposes. Except in few cases where a specialist is required for a task within a job role, functional competency models are used for determining personal training and CPD requirement for employee. As designers are also expected to be competent in other non-waste related tasks such as design functionality and energy performance, waste management competencies tend to have implication for professional development and training. Heffman and Flood (2000) noted that significance of competency-based measures in tailoring staff training could not be over emphasised. It is a valuable measure for promoting appropriate professional approach and behavioural patterns that are capable of facilitating organisational goal.

Without expatiating on the nature of training needed, Lu and Yuan (2010), Wang et al. (2014) and Yuan (2013b) identified education and training as a means of reducing waste intensiveness of the construction industry. In order to design out waste, this study provides the basis upon which education and training of design professionals could be based. Thus, the study has implication at organisational, team and individual levels.

At organisational and team level, there is need to adapt firm practices to the industry standards. This is expected to cover detailing pattern, design vocabulary, specification and documentation, while also improving knowledge and database of low waste and secondary materials available for specification. Along with training in low waste design skills, construction operation sequence and materials options, proficiency in performing design task to conventional standard is expected to be improved through Continuous Professional Development (CPD) programmes. In addition, design managers are not only expected to be versed in design coordination and clash prevention, inter-professional collaborative competencies is required of designers in preventing waste due to information loss and inadequate collaboration. In line with strategy for consolidating competency within an organisation (Prahalad and Hamel, 1990), inter-professional collaborative competencies, such as communication and clash prevention, might be the criteria for redeployment of staff to design management unit of a firm.

Albeit clear impacts of training and education, awareness of design causes of waste, personal and organisational commitment to designing out waste are requisite to ensuring effectiveness of the training program. Thus, there is need for cultural shift from end of pipe treatment of waste to designers' self-dedication to designing out waste. While it seems to be an organisational role to equip their design team with the right competencies, this study also implies that individual designers should improve their task proficiency, low waste design skill, construction related knowledge and inter-professional collaborative competencies. In addition, dedication and commitment to designing out waste should be corroborated by knowledge of the design causes of waste. Thus, designing out waste requires improvement of both cognitive abilities and personality variables.

Concurrence of the Findings with Theory

This study shows that the task-contextual model is a valuable framework for mapping out competencies required for an effective job performance. Table 3 shows a number of competency variables that contributes to the key competencies for designing out waste. In figure 3, the competencies were correlated with task-contextual framework. Concurring with the tenet of its theoretical basis, the study suggests that both task and contextual performance are measures of competencies for designing out waste. This particularly signifies the relevance of both task and contextual variables as key competencies required for designing out construction waste. It similarly suggests the need for effective cognitive and personality related ability as a designer. With respects to the task performance, the study identifies measures that corresponds to task skills, task knowledge and task habits, which are the three aspects of task performance as defined by the task-contextual framework. At the level of contextual competencies, contextual skills, knowledge and habits are all accounted for. These were established in terms of self-dedication and commitment to waste management as well as inter-professional facilitation. This also confirms the antecedent position that contextual performance, such as interpersonal relationship are more likely to determine personality factor in a managerial role (Motowildo et al., 1997).

Although limitation of this study to qualitative approach prevents its tendency to determine which of task or contextual factors is more predictive of the desired competencies, more task related factors are mapped out in the study. This tends to follow the same pattern as Ahadzie et al. (2014), which suggest that, unlike construction stage, design stage tends to require more task competencies than contextual competencies. The finding is not surprising as the need for contextual competencies is proportionate to level of job autonomy (Gellathy and Irving, 2009). At the design stage of collaborative projects however, there is usually low level of job autonomy for each party (Ahadzie et. al., 2014), especially as everyone work together to set right the project objectives. This explains the need for more task related factors than contextual variables as suggested by the study. This is not only as a result of the fact that group’s commitment to waste management is more likely to drive individual’s commitment, effective communication and inter-professional facilitation is a key aspect of collaborative contractual agreement. As such, the less significant the contextual variables in a contractual agreement, where collaboration is already required. In a traditional procurement route however, contextual ability and personality related competencies could be more likely to determine waste effectiveness of a design project.

Further conforming to the theory, both cognitive and personal abilities are important variables for measuring designers' competency. As predicted by Motowildo et al. (1997), this study also suggests that other than task related factors, task habits, which is a cognitive ability variable, have impacts on behavioural competence, a personality variable. While dedication to waste efficient projects is determined by contextual commitment, it also relates to task habit, which is the characteristics tendencies to exert high level of effort (Borman and Motowildo, 1993). This generally suggests that, as rightly predicted by the task-contextual model, proficiency in design tasks is not enough for designing out waste. It rather requires effective contextual competencies, which could however be seen as been external to the fundamental roles of designers. For instance, apart from proficiency in design task and low waste design skill, adequate inter-professional collaboration as well as construction related knowledge are required for designing out waste. This is perfectly in line with the theoretical belief that personality traits could affect task habits. As such, the study suggests that contextual knowledge essentially relates to task knowledge. Notwithstanding the fact that construction related knowledge is largely contextual to designers, proficiency in this knowledge would largely determine their task knowledge for designing out waste.

Requiring quantitative approach to validation, one area that seems to be related in partial variance with the theory is the relationship and interdependence of task skills and personality variables. With respect to designing out waste, inter-professional collaborative competency is not only determined by contextual variables, proficiency in design related tasks is perceived to be more important in collaborative environment. While working as a team, ability to coordinate design from other trades as well as clash detection requires both cognitive and personality variables. This suggests that asides relationship between task habits and personality variables (Motowildo et al. 1997), task skills could also affect contextual performance. This depends on the extent of task skill and knowledge required for successful inter-professional collaboration. In the case of designing out waste, design task proficiency is a requisite to effective performance at inter-professional team level. Nonetheless, establishing such relationship requires quantitative approach to enquiry.

Overall, the findings of this study has demonstrated the relevance of task-contextual framework in evaluating competencies of designers. The study has demonstrated the relevance of both task and contextual competencies as requisites for designing out waste. It has also shown that within the functional roles of designers, both task and contextual activities are not mutually exclusive. Albeit the findings that task proficiency would enhance inter-professional performance, which is a contextual activity, behavioural competencies would determine whether the task skills and knowledge would be deployed for the required activities. Although the findings of this study could be used in determining training needs and professional development for designers, a subject of further study is to determine the proportional significance of each of the task and contextual competencies. Apart from designing out waste, the extent to which the model could predict other functional roles of designers could also be explored.

Conclusion

Design stage has been reckoned as a significant stage for preventing waste generated in the construction industry. Due to evident importance of competence-based management in achieving desired change in organisational settings, this study maps out designers' competencies for designing out construction waste. Combining focus group discussions with retrospective and concurrent verbal protocol analyses, the study suggests that five competency categories, ranging from job skills and knowledge to inter-personal relationship, are indispensable to achieving waste efficient design. These include design task proficiency, low waste design skills, construction related knowledge, behavioural competence and inter-professional collaborative competencies. Although more task related measures are mapped out in the study, both task and contextual competencies are important for designing out waste.

As a competence-based research, this study has immense implications for professional development and training at individual, team and firm levels. While inter-professional collaborative competency is particularly required of design managers, other areas are requisites for designing out waste. These include proficiency and conventionalism in basic design task, knowledge of construction operation, materials and sequence, and low waste design skills. As dedication and commitment of designers determines their attitudes to waste management, this study calls for cultural change from belief in waste inevitability.

Albeit conformity of this study to the task-contextual theory of job performance, it theoretically suggests that, where job roles require inter-professional collaboration, task skill as a cognitive ability could determine personal performance at contextual level. In addition to determining the category of competency that is more predictive of designers' competencies for designing out waste, theoretical implication of this study suggests an agenda for further quantitative approach to enquiry. As this study is exploratory in nature, other studies employing quantitative approach could determine generalizability and transferability of its findings. As competency-based measure is pertinent to achieving desired professional development, further studies are required to determine competencies for preventing waste at procurement and construction stages of project delivery process. With designers' competencies for overall performance being currently unaddressed, more studies are also needed in this direction.

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