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Influence of Construction Materials Supply Chain Network Structures and Strategies on Project Delivery in Obafemi Awolowo University, Ile-Ife, Nigeria

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Abstract
The selection of type of contract for specific materials supply chain has been identified as one of the factors affecting materials management; and also affecting the objectives of construction material supply chain network systems which are the minimization of procurement cost, enhancement of material delivery and quality improvement. However, the influence of supply chain network systems as being practiced in the Nigerian Construction Industry on project delivery has not been well researched into. Therefore, this study carried out a questionnaire survey to address the problem. In total, 60 questionnaires were administered to small contractors and material suppliers in the study area with a response rate of 100%. The data was analysed using percentage tables, relative importance index, linear regression and Pearson's coefficient of correlation and determination. The findings revealed that the use of phone and personal interaction are the network systems employed by small contractors to relate with material suppliers as both systems ranked 1st and 2nd respectively. The findings also revealed that suppliers and small contractors are not employing Information Technologies in their supply chain network, and that strategies employed by contractors to select suppliers have positive influence on cost, quality and schedule of projects.
Keywords: Construction materials, Supply Chain Network, Supply chain.

1. Introduction

Construction materials are physical resources used in the construction of a project (Waste and Resources Action Programme, 2007); they are essential in construction projects and therefore should be given special attention in a project plan as the quality of materials can influence the quality of the final product and untimely delivery of construction materials can affect the performance of a project in terms of cost, time and productivity (Al-Shorafa, 2009; Zohreh et al., 2013). Gulen (2007) observed that materials required for a construction project consume up to 80% of total construction cost. Also, Ward-Harvey (2009) noted that industrialization has enormously expanded the range of materials used in construction and that many buildings have developed serious defects because of the lack of knowledge of certain characteristics of new materials, thereby making the contractor and other project team members responsible for the choice of materials and assembly methods, and also requiring the construction professionals, especially contractors to have a very broad understanding of a wide variety of materials, their potentials and deficiencies, and supply chain systems. The flexibility added to construction projects execution by the new innovative methods is affecting material delivery processes (Koskela and Howell, 2002 cited in Ala-Risku and Karkkainen, 2005). The delivery processes affect material availability and for materials to be available on time, a pro-active material delivery method is required for construction projects (Ala-Risku and Karkkainen, 2005). Over the years, contractors have been ordering materials in advance as a system of reducing the risk of late delivery of materials. However, this system creates problems for materials handling and safety on site (Karkkainen et al., 2003 cited in Ala-Risku and Karkkainen, 2005).

The rising costs of materials and low productivity of workers are the key drivers to improving the system of managing materials (Technology Strategy Board, 2007). Also, Dey (2001) cited in Al-Shorafa (2009) identified the selection of type of contract for specific materials supply chain as one of the factors affecting materials management. Ogunsanmi (2013) found that supply chain selection factors have impacts on project performance and recommended that adequate attention should be given to the selection of appropriate supply chain methods. Rasid et al. (2006) cited in Ogunsanmi (2013) argued that different supply chain methods offer different organizational approach which is capable of affecting project performance. The objective of any construction material supply chain network systems is the minimization of procurement cost, enhancement of delivery and improving quality (Castro-Lacouture and Skibniewski, 2007); yet research has shown that uncertain demand and late ordering and delivering of materials are some of the problems of material supply chain causing these objectives to be unachievable in construction projects (Vrijhoef and Koskela, 2000 cited in Ala-Risku and Karkkainen, 2005). As noted by Ala-Risku and Karkkainen (2005), an interactive material supply chain network is needed where the sequence of work and materials required are derived from the state of work on site. Muralidharam et al. (2002) opined that the procurement of the right quality of materials in the right quantity from the right supplier at the right time and at the right price is one of the responsibilities of a value-giving contractor; however, contractors have focused mainly on obtaining the lowest unit prices by trading-off of good

quality and timely delivery for poor quality and erratic delivery of materials (Gulen, 2007). Although, supply chain systems abound in the Construction Industry but deciding on a system that is capable of improving the success of a project is a challenging task. This decision must be made early in the project and the potential effect of the selected system should also be considered (Cooperative Research Centre for Construction Innovation, 2008). Supply chain in construction requires a range of knowledge and skills, some of which are developed through practical experience in construction procurement processes. Also, the need to control cost and quality have placed more emphasis on the supply chain process (The American Institute of Architects, 2000) and on the contractor to select the supply chain system that will ensure the availability of materials as at when required and in the right quality (Dey, 2001 cited in Al-Shorafa, 2009).

The delivery of construction projects is characterized by rising complexity, uncertainty, instability and volatility (Mwikali and Kavale, 2012) and the contributions of suppliers to project delivery cannot be underestimated. Suppliers directly influence either positively or negatively, the cost, quality, technology, delivery, flexibility and profits of contractors (Kranse and Scannell, 2002; Monczka et al., 1998 cited in Ho et al., 2007). Firms and contractors operating in the same industry use different criteria to select their suppliers because there has not been any general criteria for selecting and evaluating suppliers. Therefore, an efficient supplier selection process needs to be in place for successful and effective supply chain network, which will ameliorate the quality of construction projects in the Construction Industry (Ho et al., 2007).

This paper aims to reveal the commonly procured construction materials by contractors, medium of contracting material suppliers and systems of material supply chain network used by contractors in the Nigerian Construction industry using Obafemi Awolowo University, Ile-Ife, Nigeria as a case study. The paper will also investigate the mode of paying material suppliers in the supply network, methods of determining the quality and quantity of materials delivered to site, the criteria used by small contractors in selecting material suppliers and the influence of supplier selection criteria on project delivery in the study area. It is aimed that the findings of this paper will reveal the influence of material supply chain network systems on project delivery in the Nigerian Construction Industry.

2. Supply chain network

Cooper et al. (1997) defined supply chain network as an element of supply chain management that details the supply chain business processes from purchasing, management, production, and distribution to customers. Other elements of supply chain management include; supply chain business processes and supply chain management components. Bhattachara (2010) cited in Kilic (2012) described supply chain network as a process of planning, implementing and controlling the supply operations. According to Buyukozkan (2011) cited in Kilic (2012), supply chain network depicts the flow of materials or services from the suppliers to the user, usually the contractor. It deals with the management of materials and information across a network of organizations that are involved in the design and the production process of a project (Al-Shorafa, 2009). Zohreh et al. (2013) stated that supply chain network includes all the activities related to material and information flow among the members of the chain involving the suppliers, contractors and clients. Al-Shorafa (2009) developed a framework for material supply chain process through the project phases. The framework consists of six phases such as bidding, sourcing, procurement, construction, post construction and evaluation phase. However, the main problem of supply chain network according to Alarcon et al. (1999) is related to delay and lack of specified quality and the way to improve on material supply chain is through collaboration and the application of Information Technologies to the supply network. Cooper et al. (1997) maintained that an improved supply chain network could increase the operation accuracy for costs saving and promote the competitiveness of firms.

2.1 Material supply chain systems

Public Procurement Guidelines (1994) opined that a competitive method of supply chain carried out in an open, objective and transparent manner can achieve best value for money, and that better value for money can be achieved by seeking suppliers outside the region of work and observing essential principles of procurement function which include; non-discrimination, equal treatment, transparency, mutual recognition, freedom of establishment, proportionality, and freedom to provide service. Waste and Resources Action programme (2007) stated that materials should be requisitioned to highlight the immediate area and programme for their intended use prior to ordering of materials. Rosli et al. (2006) and Rawlinson (2006) asserted that different supply chain systems have different effect on the cost, time and quality of the project. Authors have developed and researched into different supply chain systems; one of such systems is open competitive system suggested by Guide 3 to Sustainability Procurement (2010); a system that lays emphasis on the specification and bid evaluation. Also, Muralidharam et al. (2002) proposed a system that selects suppliers using quality, price, delivery and service as criteria. Kilic (2012) proposed a systematic supply chain system based on a fuzzy multiple criteria decision-making. The system, according to the author is capable of determining the most suitable supply chain network. Ala-Risku and Karkkainen (2005) proposed a shipment tracking-based approach to provide inventory

transparency for managing the material logistics of construction projects. Castro-Lacouture and Skibniewski (2007) proposed E-work model as a suitable method of managing construction materials, the system was argued to have the potential for predicting materials requirements with the use of task administration protocols and autonomous agents. Gurler (2007) identified traditional system and supplier partnering system. He argued that the traditional system lays more emphasis on price, evaluates bids, involves many suppliers and usually it is a short-term contract based system. On the other hand, supplier partnering system involves fewer selected suppliers, evaluates by commitment to partnership, employs multiple selection criteria and it is a long-term contract based method. AK Steel Supplier Requirements (2013) identified purchase order, emergency ordering and supply agreements as material supply chain systems. The supply agreement system is a form of a long-term agreements usually 2-5year between the contractor and the supplier. Other supply chain systems proposed by authors are Linear Weighting system using supplier rating (Petroni and Braglia, 2000), Artificial Neural network (Choy et al., 2002), Multiple Attribute Utility Method (Zhaw and Bross, 2004), and Fuzzy Multiobjective and Additive Model (Amid et al., 2009).

2.2 Supplier selection criteria

Supplier selection is a crucial stage in the procurement process and the criteria for selection must be decided before the commencement of the procurement process. The extent and complexity of selection criteria should reflect the nature of the contract and must be logical and well-structured to avoid implication of impropriety (Guide 3 to Sustainability Procurement, 2010). Murallidharam et al (2002) argued that the basic selection criteria are quality, price, delivery and service. Ellram (1990) proposed the use of financial statement of the supplier, organizational culture, and strategy of the supplier and the technological state of the supplier as principal criteria for selecting suppliers. A survey of how construction firms in Taiwan and Vietnam relate with suppliers was carried out by Ho et al. (2007), the study found that on-time delivery and quality performance play a very important role in the selection process of suppliers in Taiwan and Vietnam Construction Industries. Kannan and Tan (2002) cited in Ho et al. (2007) suggested the use of delivery and service quality, information sharing and responsiveness, quick response time in case of emergency and special request and flexibility to respond to unexpected demand changes, as evaluation and selection criteria for suppliers. Mwikali and Kavale (2012) reviewd literature and identified cost, technical capability, quality assessment, organizational profile, service levels, supplier profile and risk factors as factors affecting the selection of optimal supplier. According to Monzka et al. (1998) cited in Ho et al. (2007) suppliers can be evaluated using their management capability, personnel capabilities, cost structure, total quality performance systems and philosophy, process and technological capability, regulation compliance, financial stability, delivery performance, information systems capability, purchasing strategies and techniques, and longer-term relationship potentials.

3. Methods

Literature review and questionnaire survey were adopted to achieve the objectives of this study. The questionnaire was structured into four parts. The first part covers general information on respondents and their organizations. The second part covers the commonly procured construction materials by respondents and the medium of contacting material suppliers. The third part was structured to collect information on the methods of procuring construction materials and mode of paying material suppliers by respondents. In the fourth part of the questionnaire, Likert scale questions were structured to collect information on the methods of determining the quality and quantity of materials delivered to respondents. The criteria used by respondents in selecting material suppliers; and the effects of suppliers selection criteria on project delivery.

Twenty-two construction sites were identified on Obafemi Awolowo University campus and thirty-eight construction material suppliers were selected for this research based on their proximity to the identified sites and the history of their patronage by contractors. Sixty questionnaires were administered altogether, 22 to the contractors and 38 to suppliers. The response rate was 100% as all the 60 questionnaires were returned.

Data collected were analysed using percentage tables, relative importance index (RII), linear regression, Pearson's coefficient of correlation and determination. The RII and the Pearson's coefficient of correlation (r) were determined using formula used by Shiau Ling (2006):

$RII = SWV/\Sigma xi$

Where $SWV = \sum xiyi$

xi = number of response to rating ij

yi = value of rating, i = 1- 5

The value of r ranges from +1 to -1

Where, +1 indicates maximum positive influence

0 indicates no influence

-1 indicates maximum negative influence

< 0.3 indicates low influence

0.3 < 0.5 indicates moderate influence
0.5- 1.0 indicates high influence

3.1 Findings and discussions

Table 1 shows that 65% of respondents very highly procures sand as a construction materials, 11.7% highly procures sand; while 18.3%, 1.7% and 3.3% of respondents indicated low, very low and not at all. 63.3% of respondents indicated that their procurement of granite as a construction material is very high, 13.3% indicated that their procurement of granite is high; while 16.7%, 15.0% and 1.7% indicated low, very low and not at all. On the procurement of cement as a construction material, 3.3% indicated that they have never procured cement before; 10.0% indicated that their procurement of cement is very low; while 71.7%, 5.0% and 10.0% indicated that their procurement of cement is very high, high and low respectively. 36.7% of respondents indicated that their procurement of paints is very high, 38.8% indicated high, 8.3% indicated low, 3.3% indicated very low, while 13.3% indicated not at all. On the procurement of roofing materials and electrical materials, 53.3% and 23.3% indicated very high, 15.0% and 40.0% indicated high, 8.3% and 16.7% indicated very low, while 8.3% and 10% indicated not at all. On the procurement of other construction materials, 28.3% indicated very high, while 13.3%, 20.0%, 21.7% and 16.7% indicated high, low, very low and not at all respectively.

Table 2 shows the medium through which contractors contact their suppliers. The table revealed that phone is the medium most used by the contractors to contact their suppliers, the use of personal contact ranked 2nd ; while the use of a close acquaintance and the use of e-mail ranked 3rd and 4th respectively. The use of other medium by the contractor to contact their suppliers ranked 5th.

Table 3 shows the systems of material supply chain network used by respondents. The table revealed that contractors usually procure materials on phone as the method ranked 1st. the use of personal contact ranked 2nd; while the use of verbal instruction, use of procurement officer, use of local purchase order, use of intermediate firm, and use of other methods ranked 3rd, 4th, 5th, 6th and 7th respectively.

Table 4 shows the mode of paying material suppliers by the contractors. It was revealed in the table that payment immediately after supply is most used by the contractors. Payment in advance of supply is the 2nd most used approach. The 3rd, 4th and 5th approaches are payment a week after supply, payment a week after supply, and payment more than a month after supply.

Table 5 shows the methods of determining the quality and quantity of materials delivered to site by contractors. 91.7% of respondents indicated that they compare deliveries with a model piece and 8.3% indicated that they do not. 71.7% indicated that they carry out acceptance test and 28.3% indicated that they do not carry out acceptance test. Visual observation is used by 86.7% of the respondents and direct measurement is used b 93.3% of the respondents; while 10.0% do not use visual observation and 6.7% do not use direct measurement. Also, 70.0% indicated that they judge the quantity of deliveries by vehicle capacity and 30.0% indicated otherwise.

Table 6 shows the criteria for selecting material suppliers by respondents. According to the table, the quality of materials supplied by the suppliers is the most important criteria; which is closely followed by the quantity of materials required by the respondents. Previous experience of the contractor with suppliers which is the performance of suppliers on past project ranked 3rd; while nature of project, types of materials handled by suppliers, and location of suppliers ranked 4th, 5th and 6th respectively.

Table 7 shows the components of project delivery, criteria for selecting suppliers and the relationship between these components and the supplier selection criteria. Using Pearson's correlation coefficient, the table reveals that, the relationship between project's quality and criteria for selecting suppliers are 0.871, 0.855, 0.733, 0.693, 0.645 and 0.459 respectively. The relationship between cost of a project and criteria for selecting suppliers are 0.574, 0.561, 0.713, 0.932, 0.911 and 0.766 respectively; while the relationship between project's duration and criteria for selecting suppliers are 0.404, 0.309, 0.525, 0.637, 0.586 and 0.4487 respectively. These values shows that there is significant positive relationship between project delivery and criteria for selecting suppliers, since all the coefficients of correlation are highly significant values that cannot occur by chance given the level of significance of 0.01 and also because the values tend towards +1.

4. Conclusions

This study has made available information on the types of materials commonly procured by small contractors, the medium of contacting material suppliers, the systems of material supply chain network used by small contractors, and mode of paying material suppliers. Also, the study has provided information on methods of determining the quality and quantity of materials delivered to site, the criteria used by small contractors in selecting material suppliers, as well as the effects of supplier selection criteria on project delivery.

From the findings of this study, it can be deduced that small contractors highly procure construction materials. This deductions indicate that the small contractors must have methods and medium of contacting the suppliers. The use of mobile phone was found to be the network system most used by small contractors to relate

with material suppliers, indicating that there is a form of long-term and close relationship between the small contractors and the suppliers. It can also be inferred from the personal interaction between the small contractors and suppliers that contractors do not trust the suppliers to adhere to the specified quality and quantity of materials and also that the suppliers do not trust the contractors to pay promptly.

The findings of this study revealed that quality and quantity of materials delivered to small contractors and previous experience of small contractors with the suppliers are the criteria that mostly influence project delivery components. Materials delivered to contractors in the specified quality and right quantity will help the small contractors to control cost overrun and will help increase the quality of work.

The cost of delivering materials to site can also be reduced by procuring them from suppliers in close proximity, which is one of the reasons small contractors employ the location of suppliers as a selection criteria and also why the location of suppliers has a positive influence on the cost of a project. Generally, the strategies used by small contractors in supply chain network to select material suppliers have positive influence on cost, quality and schedule of projects.

Finally, the findings also revealed that suppliers and small contractors are not employing Information Technologies in their supply chain network; the use of e-mail in the supply chain network is not encouraging and this would have facilitated the adoption of e-procurement method in the Nigerian construction industry if it has been embraced.

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Table 1: Commonly procured construction materials

materials	**Percentage (%)**				
	Very high	High	Low	Very low	Not at all
Sand	65.0	11.7	18.3	1.7	3.3
Granite	63.3	13.3	16.7	5.0	1.7
Cement	71.7	5.0	10.0	10.0	3.3
Paints	36.7	38.3	8.3	3.3	13.3
Timber	63.3	16.7	10.0	5.0	5.0
Roofing materials	53.3	15.0	8.3	15.0	8.3
Electrical materials	23.3	40.0	10.0	16.7	10.0
Others	28.3	13.3	20.0	21.7	16.7

Table 2: Medium of contacting material suppliers

media	**Very often (5)**	**Often (4)**	**Seldom (3)**	**Rarely (2)**	**Very rarely (1)**	**Sum weighted value (SWV)**	**RII**	**Deviation**	**Ranking**
Phone	49	9	1	1	0	286	4.760	1.225	1
e-mail	3	9	12	15	21	138	2.300	-1.235	4
Personal contact	37	18	5	0	0	272	4.533	0.998	2
Through a close acquaintance	13	33	10	4	0	235	3.917	0.382	3
Others	3	5	10	24	17	130	2.167	-1.368	5
Total							17.677		
Mean							3.535		

Table 3: Systems of material supply chain network used by small contractors

Procurement methods	Very often (5)	Often (4)	Seldom (3)	Rarely (2)	Very rarely (1)	Sum weighted value (SWV)	RII	Deviation	Ranking
Local purchase order	7	23	10	11	9	188	3.133	-0.122	5
phone	46	10	4	0	0	282	4.700	1.445	1
Personal interaction	36	20	4	0	0	272	4.533	1.278	2
Verbal instruction	25	29	6	0	0	259	4.317	1.062	3
Use of procurement officers	3	36	19	1	1	219	3.650	0.395	4
Use of intermediate firm	2	11	17	12	18	147	2.450	-0.805	6
Others	0	1	7	27	24	103	1.717	-1.538	7
Total							22.783		
Mean							3.255		

Table 4: Mode of paying material suppliers

Mode of payment	Very often (5)	Often (4)	Seldom (3)	Rarely (2)	Very rarely (1)	Sum weighted value (SWV)	RII	Deviation	Ranking
Payment immediately after supply	40	14	6	0	0	274	4.567	1.274	1
Payment in advance of supply	18	28	11	1	2	239	3.983	0.690	2
Payment a week after supply	5	25	22	2	6	201	3.350	0.057	3
Payment a month after supply	2	8	23	12	15	150	2.500	-0.793	4
Payment more than a month after supply	6	0	10	20	24	124	2.067	-1.226	5
Total							16.467		
Mean							3.293		

Table 5: Methods of determining the quality and quantity of materials delivered to site

Methods	Percentage (%)	
	Yes	No
A: Quality		
Comparing deliveries with a model piece	91.7	8.3
Carrying out acceptance test	71.7	28.3
Visual observation	86.7	10.0
B: Quantity		
Direct measurement	93.3	6.7
Indirect measurement (judging by vehicle capacity)	70.0	30.0

Table 6: Material suppliers' selection criteria

Supplier selection criteria	Very high (5)	High (4)	Low (3)	Very low (2)	Not at all (1)	Sum weighted value (SWV)	RII	Deviation	Ranking
Nature of project	35	20	2	3	0	267	4.450	-0.051	4
Types of materials handled by suppliers	20	38	2	0	0	258	4.300	-0.201	5
Material quantity	44	13	3	0	0	281	4.683	0.182	2
Quality of material	45	13	2	0	0	283	4.717	0.216	1
Location of suppliers	29	20	6	5	0	253	4.217	-0.284	6
Previous experience with supplier	40	18	2	0	0	278	4.633	0.132	3
Total							27.005		
Mean							4.501		

Table 7: Effect of supplier selection criteria on project delivery

Criteria for selecting suppliers	Project delivery components					
	Quality		Cost		Time	
	Pearson's coefficient (r)	Level of significance (P)	Pearson's coefficient (r)	Level of significance (P)	Pearson's coefficient (r)	Level of significance (P)
Nature of project	0.871	0.01	0.574	0.01	0.404	0.01
Types of materials handled by suppliers	0.855	0.01	0.561	0.01	0.309	0.01
Material quantity	0.733	0.01	0.713	0.01	0.525	0.01
Quality of material	0.693	0.01	0.932	0.01	0.637	0.01
Location of suppliers	0.645	0.01	0.911	0.01	0.586	0.01
Previous experience with supplier	0.459	0.01	0.766	0.01	0.487	0.01

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