Identifying Potential Critical Risks in the Construction Supply Chain – An Empirical Study in Ghana

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ABSTRACT

Risk management is an important tool for organizations operating in a global environment. Hence, this paper seeks to identify potential critical risks existing in the construction supply chain (SC) in order to aid risk management processes. From the literature, 11 risks factors that may affect the construction SC were identified. A questionnaire survey based upon these factors was then carried out and 49 responses were received from contractors and suppliers in Ghana. The mean score analysis was used together with the one-sample t-test to identify potential risks in the construction SC. The K-S test was used to investigate any differences between ratings given by the two groups of respondents for a particular risk factor. The internal consistency and reliability of the risk factors was assessed using the Cronbach's alpha coefficient (α).The results show that fluctuations in prices, changes in interest rates, shortage of materials, frequent changes in SC inputs and unexpected changes in demand are potential critical risks. Generally, there was no statistical difference between the perceptions of the stakeholders on the ranking of the risk factors. Using the research presented, readers are able to identify potential risks in the construction SC for risk management activities and implement suitable risk mitigation. Although a plethora of research exists on

risk management, few studies have attempted to identify risks in the construction SC – this research goes some way to fill that void.

KEYWORDS: Construction, Risk Management, Risk Typology, Supply Chain, Supply Chain Management

INTRODUCTION

Risk permeates every aspect of life and is encountered and managed in every dimension on a daily basis. It is not surprising therefore that the subjects of risk and risk management have received extensive attention within the academic discourse. In most fields of management control and decision making, risk management has emerged as an important aspect of modern construction management (Giannakis et al., 2004; Mallman, 1996). In the field of supply chain (SC)[1] management (SCM), Brindley (2004) evaluated the evolution and nature of risk management and its contributory factors, and suggested that the adoption of risk management approaches could be beneficial to organizations that are seeking technological advancements, global competition and competitive advantage; a view supported by Christopher and Lee (2004). In order to devise/ develop appropriate performance measures and metrics to educate, evaluate and direct organizational strategic decisions, it is imperative to underline these developments within supply chain risk management (SCRM) (Ritchie and Brindley, 2007). Many firms in recent times operate within global environments and are reliant upon SCRM (Manuj and Mentzer, 2008; Norrman and Lindroth, 2004; Christopher and Lee, 2004). However, the management of risks has become increasingly arduous because market globalization has created

[1] The supply chain (SC) is defined as a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services for customers (Christopher, 1992).

greater uncertainties in demand and supply and shorter technology and product lifecycles (Rao and Goldsby, 2009; Christopher and Lee, 2004).

SCRM aims at identifying the potential sources of risks and implementing suitable actions to contain or avoid vulnerability (Ritchie and Brindley, 2007). Jüttner et al. (2003) proposed four key constructs of the SCRM concept that can allow the identification of critical aspects of this managerial concept: *"i) assessing the risk sources for the supply chain; ii) identifying the risk concept of the supply chain by defining the most relevant risk consequences; iii) tracking the risk drivers in the supply chain strategy; and iv) mitigating risks in the supply chain."* Rao and Goldsby (2009) reviewed the literature on SCRM and observed that a well-developed body of knowledge exists for managing risks but limited research has been undertaken to identify risks (Tang, 2006); hence research in this area is urgently needed. Within a construction context, a project's SC may comprise of numerous firms, equipment and materials suppliers, contractors, subcontractors, consulting firms, design and engineering firms etc. (Taylor and Bjornsson, 1999). This SC is highly fragmented, involving both small and medium size subcontractors and suppliers (Briscoe et al., 2001). Often, materials have to be imported (particularly in the developing country of Ghana) and this makes the SC global and consequently, more challenging to manage. In addition, construction projects require a high degree of coordination among the various parties who may have conflicting interests (Wong, 1999). In such an environment, risks are inevitable and so the potential benefits of SCRM cannot be overemphasized (Kumar and Viswanadham, 2007). During project execution, when a risk event occurs, project managers are required to take necessary actions using largely their own knowledge, judgement and experience. Although a project manager's tacit knowledge may be helpful in identifying and managing the potential risks posed by a new project, this useful information is rarely documented into reusable information (Kumar and Viswanadham, 2007). This makes risk(s) identification and management throughout the SC difficult or impossible to manage effectively and efficiently. According to Kumar and Viswanadham (2007), following contract signature, the problem of dealing with risks in the SC, at various operational and strategic levels, is twofold. First, preventive risk management has to be implemented and this involves: identification of potential risks, prioritization of the risks and developing approaches for minimizing the probability of their occurrence. Second, SC members have to implement 'interceptive risk management' in which appropriate and effective decisions must be made on the best action to be taken when a risk event occurs in order to contain loss.

A systematic approach to identifying emergent risks in the construction SC represents a critical step for the SC members to effectively manage risks; however, there is scant reliable information that can assist in such a process (Rao and Goldsby, 2009; Aloini et al., 2012; Vrijhoef and Koskela, 2000). Therefore, this paper aims to investigate potential risks in the construction SC using a combination of literature synthesis and a questionnaire survey in developing country of Ghana. The objectives are: to provide researchers and practitioners with information on general risks posed within in the construction SC; and augment the efficiency and effectiveness of any future control measures implemented to mitigate these.

SUPPLY CHAIN AND SUPPLY CHAIN MANAGEMENT

Ali (2014, pp. 18) wrote that the: *"supply chain is a system in which suppliers of raw material, manufacturing process, product distributors and customers are connected to one another* *through a stream of materials and a stream of data."* Indeed, the chain includes all activates ranging from raw materials extraction through to delivering of the final product. It can also be defined as the strategic and systematic balance of companies commercial activities, and the utilization of processes between commercial activities to improve long-term company performance (*ibid*). The origin of SCM dates back to the 1980s when it was first introduced by the manufacturing industry, primarily for the control of logistics. Shingo (1988) implemented one of the earliest applications of SCM via Just-In-Time (JIT) delivery systems as part of the Toyota production plant. SCM literature has since developed at an exponential rate and has been applied to a myriad of industrial settings. Regardless of industrial setting or application, the overarching aims of SCM are to reduce cost and ensure that every member of the SC attains profit. However, to be successful or efficient, the SCM system must take into account, integration hence, the need for collaboration, cooperation, trust, technology and information sharing and partnerships vis-a-vis managing functional processes individually (Akkermans et al., 1999; Chan and Qi, 2003; Ashish and Ravi, 2002).

To enable the development of economies of scale and specialization, it is necessary to separate the SC activities between different organizations (Albaloushi and Skitmore, 2008). Subsequently, there are several crucial problems and issues that need to be addressed for successful SC operations; this being the fundamental motive of SCM (Trkman et al., 2007). Among these important issues are the ability to coordinate SC partners and their activities, and uncertainties involved (Sunil and Peter, 2004; Turban et al., 2004). However, maximizing the efficiency of the individual links within the chain does not guarantee an overall system optimization. For example, due to personal hindrances and lack of information, optimum decisions may not be achieved even after ensuring that decision makers are integral to the SC (McGuffog and Wadsley, 1999). Given this, the implementation of SCM can be problematic and barriers impeding the successful implementation of SCM include:

- *Information processing barriers*: Distortions in demand information that can lead to an increased variability in SC orders, due to the movement of information between the various stages of the SC.
- *Incentive barriers*: Actions resulting from offering of incentives to SC members can lead to increased variability/ uncertainty and a reduction in overall SC profits.
- *Pricing barriers*: When pricing policies of a product seem to affect the variability of orders placed.
- *Behavioral barriers*: Problems related to learning within organizations that contribute to what is known as the bullwhip effect; such problems are normally caused by faulty communication between different SC stages and the manner in which the SC is organized.
- *Operational barriers*: Operational barriers refer to those actions involved in the filing and placing of orders that lead to an increased order variability (Sunil and Peter, 2004).

Supply chain management in construction

Tommelein et al. (2003, pp.1) mentioned that SCM is: *"recognized as a leading process improvement, cost saving and revenue-enhancing business strategy practiced in today's business world. All disciplines within a business (conceptual design, engineering, procurement, fabrication, logistics, construction, accounting and legal council) can be, and most often are,* *involved in SCM."* Accordingly, SCM practices have been applied extensively in the construction sector. A number of SCM initiatives launched by the construction industry since the end of the 1980s often kindle two main discussions on the SCM concept, namely: increased economic weight of the construction SC; and lagging productivity development (Vrijhoef and Koskela, 2000). Typically, the construction SC includes the entire construction process, from the initial owner/ client's demands through to planning, design and construction, to operations and maintenance and eventual disposal of projects (Albaloushi and Skitmore, 2008). However, it also includes all the firms and stakeholders involved in the construction process such as designers, contractors/developers, owner, suppliers and subcontractors (Saad et al., 2002).

Similarly, construction SCM has been described as: *"a practice of a group of companies and individuals working collaboratively in a network of interrelated processes structured to best satisfy end-customer needs while rewarding all members of the chain. While SCM may be practiced on a single project, its greatest potential benefits come when it is practiced at the enterprise level, when it involves multiple companies, and when it becomes applied to multiple projects over an extended period of time"* (Tommelein et al, 2003, pp. 1). Moreover, aside from being a chain made of business-to-business relationships among construction businesses, the construction SC is also regarded as a network of multiple relationships and organizations, which involves the flow of funds between client, suppliers, contractors, designers, and subcontractors, flow of materials, products/goods or services and flow of information to deliver a project (Muya et al., 1999).

Understanding risk and supply chain risk management

Within in the SCM literature, the origin of the term *risk* itself has been subjected to numerous debates. While some researchers argue that the the term's origin can be traced back to the Arabic word '*risq'* (which means 'gift from God') (Norrman and Lindroth, 2004), others suggest that it was derived from the Italian word '*risicare*' (which means 'to dare') (Khan and Burnes, 2007; Bernstein, 1996). Previous systematic studies on risk could be traced to mathematicians such as Fermat and Pascal, who made an attempted to apply purely mathematical models to gambling (Khan and Burnes, 2007). However, recent studies have attempted to employ psychology-based methods and human behavior to appreciate risk and its responses (Thaler, 1985; Kahneman and Taversky, 1979). Many researchers have defined risk in various ways (March and Shapira, 1987; Rowe, 1980, Lowrance, 1980; Rao and Goldsby, 2009); however, one of the simplest and commonest definitions is *"risk refers to the possibility of loss."* Risk has also been said to be *"the potential for unwanted consequences to arise from an event or activity"* (Rowe, 1980, cited in Rao and Goldsby, 2009, pp. 99). Another more organizational-related definition of risk was suggested by March and Shapira (1987): *"risk refers to the negative variation in business outcome variables such as revenues, costs, profits, etc."* In the context of construction project management, risk has been defined as: *"an uncertain event or condition that, if it occurs, has a negative effect on project objectives"* (Aloini et al., 2012, pp. 736).

Within the extant academic literature, the nature of risk has engendered considerable debate. Decision theorists claim that risk entails the possibility of achieving performance much better than expected, and not just a downside possibility; meaning that risk is more of an uncontrollability, rather than a mere downside possibility (Arrow, 1970). Yet, most risk definitions only focus upon negative connotations that affect performance. This is not surprising because most of the time, managers are more concerned about the downside possibility and not the upside (Khan and Burnes, 2007). Moreover, Wagner and Bode (2008) reported that in the SCM context, it is merely the downside that reflects the reality of business more accurately. Therefore, as this study falls within the scope of managerial research, risk will herein be referred to within the context of a downside possibility.

Managing risk in construction SCs remains a current topic of research interests and both researchers and practitioners have conducted several key studies on SCRM (Jüttner, 2005; Khan and Burnes, 2007; Wagner and Bode, 2008; Seshadri and Subrahmanyam, 2005). For example, Tang (2006, pp. 453) proposed that SCRM is: *"the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity."* Whereas Christopher (2002) states that SCRM utilizes a coordinated approach among members of the SC to manage external risks so as to minimize the vulnerability of the whole SC. There are many other key definitions of, and discussions on the SCRM concept in the literature, which suggest that SCRM is an extension of the ideology of within-organization risk management (Rao and Goldsby, 2009; Ritchie and Brindley, 2007; Jüttner et al., 2003). Most existing studies on SCRM are generic and focus on research areas such as: international business (Oxelheim and Wihlborg, 1987); and operations management (Wu et al., 2006) vis-à-vis construction. Some of the few studies that have focused on construction SCRM include O'Brien (1999), who demonstrated cases of inappropriate prediction of risk and the importance of SCRM in construction; Kumar and Viswanadham (2007), who proposed a case-based reasoning (CBR-based) decision support system framework for construction SCRM; Long et al. (2004), who described various causes of construction projects' delay from the perspective of developing countries; and Tah and Carr (2001), who employed a knowledge engineering approach to present a qualitative risk analysis framework using object modeling for managing SC risks in construction projects.

Identification of risks in the supply chain

Rao and Goldsby (2009) conducted a thematic review of research into SCRM and concluded that limited work had been implemented to identify SC risks. This corroborates similar arguments by other researchers (e.g., Kouvelis et al., 2006), that even though the SCRM field has significantly developed alongside the parent SCM field, the literature pertaining to risk identification in SC remains scant. Yet, identifying risks remains an important step in any risk management process. Researchers (Khan and Burnes, 2007; Frosdick, 1997) suggest that it is essential for any risk management approach to follow a systematic and formal approach of identifying, quantifying and reducing risks. Though the assessment of SC vulnerability in today's complicated global economy is increasingly arduous, it is also vitally important (Sheffi, 2005). Arguing from this viewpoint, Rao and Goldsby, (2009) expressed the need for a typology that explicitly identifies the potential sources of risk in the SC. They (*ibid*) provided a comprehensive literature review on SCRM and developed a typology of risk sources for the SC, comprising of industry factors (e.g. new and existing competitors, fluctuations in users' demand and shifts in market supply), environmental factors (e.g. war, changes in government policy or regulations, price fluctuations, and changes in interest rates), decision-maker related factors (e.g. knowledge of decision makers), organizational factors (e.g. raw materials shortages, machine failure, and labor uncertainties) and problem-specific factors (e.g. complexity of decision tasks) (Saha, 2007;

Taylor, 1994; Ritchie and Marshall, 1993; Miller 1992; Ting, 1988). In developing the SC risk typology, Rao and Goldsby (2009) took into account the general risk literature (i.e. both risk management literature in relation to SCM and those outside SCRM) to identify events that initiate risks. That is, the development of the typology was based on an in-depth review of the risk literature, that synthesizes the extant literature in various areas of research, such as strategy and international business (Miller, 1992; Oxelheim and Wihlborg, 1987), operations management (Wu et al., 2006), risk management (Ritchie and Marshall, 1993) and SCM itself (Manuj and Mentzer, 2008; Zsidsin et al., 2004; Aloini et al., 2012). Given the comprehensiveness of Rao and Goldsby's (2009) literature review, it would be inappropriate to repeat similar details here and hence, their work can be adopted and tested in a new context (i.e. construction). Such analysis will provide valuable insights for researchers and practitioners who are interested in construction SCM. Hence, 11 risk factors (Table 1) that may suit construction SC in the Ghanaian setting were identified.

<Insert Table 1 about here>

RESEARCH METHODOLOGY

The literature served as the starting point for the identification of potential SC risks that were used in the development of the initial survey questionnaire. A pilot study was first carried out to test the comprehensiveness and relevance of the questionnaire prior to sending it out to the industry professionals. The pilot study involved five professionals who were familiar with this research topic. Based upon pilot study feedback, the initial questionnaire was revised to form the final questionnaire that was used to collect data. An introductory cover letter accompanied the questionnaire explained relevant definitions, provided contact details and clarified the study's objectives. The questionnaire itself comprised of two sections: 'Section A' requested background information of the respondents, whereas in 'Section B', respondents were asked to express their views on the criticality of risks (as defined in Table 1) in their SCM systems, based on a five-point Likert item rating (where 1 represented 'not critical', 3 represented 'neutral', and 5 represented 'very critical'). With the provision of a qualitative text box, respondents were given the opportunity to express their views on extra risk factors, if any.

The study's target population was all contractors and suppliers in the industry, who have extensive experience in construction SCM. Because of the absence of a reliable sampling frame for this study, it was impossible to elicit cases from a specific database using random sampling. Thus, a non-probability sampling method (i.e. snowball sampling method) was used to obtain a reasonable sample size. A non-probability sampling approach is suitable for obtaining a representative sample (Patton, 2001) and it is commonly acknowledged as appropriate when respondents cannot be randomly selected from the population but where they can be selected based on their willingness to participate in the study (Wilkins, 2011). Initial respondents were identified through a variety of methods, such as online search and professional contacts obtained from colleagues working at the Building Technology Department of the Kwame Nkrumah University of Science and Technology, Ghana. Through personal visits and telephone calls to the initially identified respondents, other potential respondents were identified. This approach helped to identify 82 qualified respondents and the questionnaires were self-administered (i.e. by hand or face-to-face) to them. The formal survey was conducted in Kumasi, Ghana in mid-January

2015. As an incentive to encourage higher response rate and participation, respondents were promised a summary of the findings upon completion of the research.

Table 2 summarizes the profile of the respondents and it can be determined that 69.4% of the respondents were contractors and the rest were suppliers – both of which are important players within the construction SC (Vrijhoef and Koskela, 2000). Regarding experience, a majority of respondents (53.1%) had 11-20 years of working experience in the construction industry but 75.5% work with less than 20 clients. The respondents' profiles illustrate that they had accrued sufficient experience of working in the industry (a subjective observation) and therefore, data collected from them should be reliable and representative.

<Insert Table 2 about here>

Method of data analysis

The data was analyzed using the Statistical Package for Social Science (SPSS 17.0 for windows). The internal consistency and reliability of the risk factors was assessed using the Cronbach's alpha coefficient (α), one of the most commonly used methods for assessing the internal consistency of scales. The value of Cronbach's alpha coefficient (α) ranges from 0-1 and it is used to assess the reliability of factors extracted from multipoint and/ or dichotomous formatted scales or questionnaires (Santos, 1999). The internal consistency of a scale is high if the α value is high. For this study, the Cronbach's alpha coefficient was 0.774, which is higher than the threshold of 0.70 (Nunnally, 1978) thus suggesting high data reliability.

Research has shown that though data obtained from Likert item responses are recognized as ordinal data, they could be analyzed using parametric data analysis techniques such as the t-test (Zhao et al., 2016; Hwang et al., 2014; Binder, 1984) and two-sample Kolmogorov-Smirnov (K-S) test (Shi et al., 2013; Lam et al., 2009). Nunnully (1975) argued that parametric statistical analysis results from ordinal data are reasonably reliable. This is because the level of flexibility and power allowed by parametric techniques can offset the few biases that they may entail (O'Brien, 1979; Allan, 1976). Parametric techniques allow easier interpretations and conclusions to provide more relevant information (Allen and Seaman, 2007). For these reasons, the *one-sample t-test* was adopted for data analysis. Moreover, since it is difficult, if not impossible, to just assume, with a fair degree of sureness, the statistical distribution of responses from different groups of stakeholders, the *K-S test* was used to investigate any differences between ratings given by the two groups of respondents for a particular risk factor (Siegel and Castellan, 1998). The study also used the descriptive analysis method *mean analysis technique*. Aside from the simplicity in terms of data presentation and interpretation from mean analysis, this method is suitable for investigating the importance and criticality of survey factors (Lam et al., 2009). For this specific work, the mean analysis and the one-sample t-test were used in this study to identify critical risks in the construction SC. The mean scores of the risk factors were computed and ranked, such that the higher the rank, the more critical the risk.

SURVEY RESULTS AND DISCUSSION

Of the 82 questionnaires distributed, 53 were received by the end of February 2015. In the first instance, it was necessary to screen the returned questionnaires. Four questionnaires were deemed invalid due a high degree of missing data. Accordingly, this study was based on 49 valid responses, representing a response rate of 59.8%. Many researchers (Ling et al., 2009; Ott and Longnecker, 2001) suggest that a minimum sample size of 30 is appropriate for statistical analysis, as it is considered representative of any group. Thus, the response rate obtained in this study was considered valid.

Risks in the construction supply chain

Table 3 summarizes the results of mean ranking analysis, one-sample t-test, and K-S tests among the respondents for the risks in the Ghanaian construction SC. The one-sample t-test was performed to test the means of all the responses to the risks, that is, to check whether the respondents' ratings for a particular risk were significant. The two-sample K-S test's results indicate that there was no statistical difference between the perceptions toward the potential risks in the construction SC (i.e. significance values being equal to or less than a threshold of 0.05) among the two groups of respondents. For research rigor, only risk factors with mean scores above 3.00 and *p*-values less than 0.05 are treated as critical. Consequently, as shown in Table 3, five risks (i.e. i) *fluctuations in prices*; ii) *changes in interest rates*; iii) *shortage of materials*; iv) *frequent changes in supply chain inputs*; and v) *unexpected changes in demand*) received significant ratings from the professionals.

Fluctuations in prices (RF_2) is ranked as the most critical risk (with a total mean score of 4.26), suggesting that contractors and suppliers in the SC are more concerned about changes in prices than any other issue. This finding concurs with Ritchie and Marshall (1993), who suggested that macroeconomic uncertainties (which include price fluctuations) are major risks in the SC. According to Miller (1992), major price fluctuations in the industry include changes in the prices of goods and services (general price inflation), and movements in the relative prices of inputs (such as labor and raw materials). Indeed, in a construction project, price fluctuations have a significant detrimental impact upon overall project cost and thereby jeopardize project success. Hence, it is not surprising to find that in a developing and an economically unstable country like Ghana, where frequent changes in prices of goods and services is a common trend, stakeholders significantly perceive price fluctuations as a critical risk in the construction SC. This highlights the need for construction organizations to incorporate price fluctuations into their risk assessment framework.

Miller (1992) stated that changes in interest rates (e.g. a very high increment in interest rates within a short period of time) is a major risk in SCs. In this study, *changes in interest rates* (RF_8) was ranked as the second most critical risk (mean = 3.72), thus underscoring the perceived importance of this risk factor. This could be due to the fact that in Ghana, almost every construction project is pre-financed by bank loans, which are affected by interest rates. Thus, because interest rates affect the amount of interest paid on bank loans, interest rate increases have an adverse and destabilizing impact upon contracts and specifically company liquidity. The high rank of this factor was also in line with the high rank of RF_2 (i.e. *fluctuations in prices*) because they are all macroeconomic issues that can have direct cost implications on the success of the SC. It can therefore be assumed that macroeconomic uncertainties (Miller, 1992) present the greatest sources of risk.

Shortage of raw materials (RF_4) was ranked third (mean = 3.68), implying that stakeholders believe that a shortage of materials affect the ability of the SC to deliver client satisfaction. This is because a dearth of materials halts project progress and causes significant project delays. This risk is very likely to be greatest when there is a single organized group or supplier responsible for the supply of critical raw materials to the firm (Miller, 1992), which is often the case in the Ghanaian construction environment. Normally, firms prefer to select specific suppliers based upon past experience with the supplier or because of personal relationships – this subjects the SC to the risk of the unique supply.

A fourth critical risk in the construction SC is *frequent changes in supply chain inputs* (RF_{11}) (mean = 3.62). This risk is linked to changes in quality of the SC inputs and it is believed to have an impact on the overall operations of the SC (Ritchie and Marshall, 1993; Miller, 1992). *Unexpected changes in demand* (RF*5*) was ranked as the fifth critical risk in the construction SC (mean = 3.53). This risk is a type of product market uncertainty that affects the performance of SCs (Miller, 1992) and relates to the predictability of the demand for a product. Rao and Goldsby (2009) argued that this shift may occur due to the availability of substitute products or due to change in customer's taste. This risk can affect contractors, especially firms offering high cost products, in the sense that they would have to write off inventory when demand slows down (Ritchie and Brindley, 2004). On the contrary, one key issue is the low rank of *policy changes* (RF_1 - ranked tenth). This risk has been found to be a non-critical risk in the Ghanaian construction SC. This happens to be in contrast with what has been reported in the literature (Saha, 2007; Ting, 1988; Taylor, 1994; Ritchie and Marshall, 1993) that changes in government policies impact the business community. No further explanation is provided for this and further research is required to investigate why this perception exists.

IMPLICATIONS AND CONTRIBUTIONS

It has been argued that risk management is an important organizational function (Giannakis et al., 2004; Mallman, 1996). Being able to identify and understand the potential risks in the SC is the first and most important step for SC risk managers. The paper has adopted and tested risk factors that have been reported within the wider literature. A major contribution of this study, is that it provides information that may be useful for the identification of potential risks in the Ghanaian construction SC. From a pragmatic perspective, construction SCRM efforts can better focus upon the risk factors that show the highest possibility of affecting the SC (i.e. the most critical risks identified in this paper). Management must recognize and quantify these risks, together with their overall impacts if productivity and performance (and ultimately profitability) is to be augmented. The study contributes to the risk management literature in two aspects. First, it adds to the so far limited literature on construction SCRM; and second, it expands the generic literature on SCRM. It is anticipated that this study will offer a basis for developing the knowledge further, by assessing the actual impacts of the risks on the Ghanaian construction SC and and extending the work to other developing countries. However, future work is required to validate the findings of this study.

CONCLUSIONS

Despite the considerable amount of research on risk management, the attention given to the identification of risk in the SC is limited, particularly in a construction context. Using a questionnaire survey conducted in Ghana, this study expands the knowledge/ literature on SCRM by identifying critical risks in the construction SC. Generally, there was no statistical difference between the opinions of suppliers and contractors on the potential risks in the construction SC.

Eleven risk factors were adopted from the literature for designing the survey questionnaire. It was found that five out of the eleven risks are deemed critical, namely: i) *fluctuations in prices*, ii) *changes in interest rates*, iii) *shortage of materials*, iv) *frequent changes in supply chain inputs*; and v) *unexpected changes in demand*. Non-critical risks were found to include *policy changes*. This could be because government policies in Ghana have very little to do with construction activities.

This study has several limitations that the future research would seek to address. Though studies on construction SC risks are lacking in Ghana, considering only 11 risk factors is not enough to reflect the overall risk conditions in the construction SC. Future research is recommended to incorporate more relevant risk factors (including construction specific factors) to broaden the understanding on them. Also, the relatively small sample size is a limitation of this study; albeit such was valid to conduct statistical analysis. A wider range of professional disciplines, including architectural firms, consulting firms, developers and owners (and from other developing countries) should also be involved in future work.

It is believed that the information provided in this paper will allow the reader to identify important risks in the construction SC and thereby facilitate the risk management process. In line with the purpose of this study (i.e. to test general SC risks in the construction context), most risk factors that are more specific to construction projects (see, for example, Aloini et al., 2012) have been reserved for future research.

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Table 1: Eleven potential risks in the construction supply chain.

Code	Risk factor	Literature
RF_1	Policy changes	Saha, 2007; Ting, 1988; Taylor, 1994; Ritchie and Marshall, 1993; Miller 1992
RF_2	Fluctuations in prices	Ritchie and Marshall, 1993; Miller 1992
RF_3	Natural occurrences (e.g., fire)	Miller 1992
RF_4	Shortage of raw materials	Miller 1992
RF_5	Unexpected changes in demand	Miller 1992
RF_6	New and existing competitors	Sutcliffe and Zaheer, 1998; Miller 1992; Porter, 1980;
RF_7	Bad debt	Kleindorfer and Saad, 2005; Finch, 2004
RF_8	Changes in interest rates	Miller 1992; Ritchie and Marshall, 1993
RF_9	Uncertain research and development results	Miller 1992
RF_{10}	Labor uncertainties (e.g., strikes)	Jiang et al., 2009; Jüttner et al., 2003; Miller 1992;
RF_{11}	Frequent changes in supply chain inputs	Miller 1992

Table 2: Profiles of respondents.

Profile	Categorization	Number	Percent
Nature of business	Contractor	34	69.4
	Supplier	15	30.6
Work experience	5-10 years	21	42.9
	11-20 years	26	53.1
	21-30 years	2	4.2
Number of clients	< 20 clients	37	75.5
	20-40 clients	9	18.4
	> 40 clients	3	6.1

Table 3: Risks in the construction supply chain.

Code	Risk factors	Mean	Rank	*p*-value	K-S test
RF_1	Policy changes	3.12	10	0.348	0.000
RF_2	Fluctuations in prices	4.26	1	0.000*	0.000
RF_3	Natural occurrences (e.g., fire)	3.26	7	0.229	0.001
RF_4	Shortage of raw materials	3.68	3	0.000*	0.000
RF_5	Unexpected changes in demand	3.53	5	0.004*	0.000
RF_6	New and existing competitors	3.14	9	0.442	0.000
RF_7	Bad debt	3.24	8	0.135	0.000
RF_8	Changes in interest rates	3.72	2	0.000*	0.000
RF_9	Uncertain research and development results	3.29	6	0.147	0.001
RF_{10}	Labor uncertainty (e.g., strikes)	3.08	11	0.642	0.000
RF_{11}	Frequent changes in supply chain inputs	3.62	4	0.000*	0.000

Note: * = the one-sample t-test result is significant at the 0.05 level.