A fuzzy-based evaluation of financial risks in build–own–operate–transfer water supply projects

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Abstract

The Build–own–operate–transfer (BOOT) scheme is widely used for the provision of new bulk water supply. However, this scheme is complex and carries significant financial risks, due to the characteristics of the water sector and the involvement of public–private stakeholders with new and extended responsibilities, large private capital, and long contract duration. Drawing on the Nungua Seawater Desalination Plant (NSDP) in Ghana, this research seeks to identify and assess the critical financial risks associated with BOOT water supply projects and evaluate the financial risk level of the NSDP project. The risks and their relative criticality on the NSDP project are investigated by using a questionnaire survey method. The questionnaire was formulated with a set of 18 risks derived from extant literature and project documentation. Perceived critical financial risks affecting the NSDP project were assessed by a team of experts who had direct involvement in the project. A fuzzy synthetic evaluation suggests that the case project is financially risky and that all the risks are critical to the project. Bankruptcy of consortium members, unfavourable economy of the host country, uncertainty in the tariff adjustment of water products, rate of return (profitability) restrictions, and availability problem of private capital are the five most highly-ranked risks. The fuzzy technique is used to represent and model the experiential knowledge of survey participants and to address the fuzziness of their expert judgments. The study's results facilitate prioritization of risks and a comprehensive risk management program during the lifecycle of the case project and future projects. The fuzzy technique is suitable for early phases of BOOT projects to prioritize the risks that require a detailed analysis and to predict the risk level of a project.

Keywords: Build-own-operate-transfer (BOOT), fuzzy synthetic evaluation, water supply, financial risk.

Introduction and research background

Build–own–operate–transfer (BOOT) arrangements have been used internationally as a means to develop new infrastructure assets. The BOOT scheme is particularly suitable for the delivery of bulk water supply (Lianyu and Tiong, 2005). From 1990 to 2011, 58% (439 projects) of

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private activities in developing countries involved water and wastewater treatment. Among which, 31% (136 projects) were drinking water supply (World Bank, 2012). The BOOT model has the advantages of assigning the risk of delivering a new bulk water supply on budget and on time to the private sector, improving the efficiency of project delivery, and mobilizing new sources of funding for fast project development (World Bank, 2014). The model has become an increasingly important route for bulk water supplies because such arrangement increases the capacity of water systems to provide potable water to a growing number of customers.

Under the BOOT scheme[1], the private developer performs new and extended responsibilities, such as raising project funds, designing and constructing facilities required to deliver the bulk water supply, and operating and maintaining these facilities, with a return on capital secured through a long-term off-take agreement (Wall, 2013; Lianyu and Tiong, 2005; Donaghue, 2002). Ownership and operating rights belong to the private entity until the expiration of the concession period, after which these rights are transferred to the public party. In this research, BOOT includes all concession-type contracts in which finance is provided primarily by the private sector to develop infrastructure assets. Variations generally adopt the primary functions of the BOOT model and include build–operate–transfer (BOT), design–build–operate–transfer, finance–build–own–operate–transfer, build–transfer–operate, build–lease–transfer, and design–build–operate. Utility concessions are excluded from consideration in this paper[2]. However, where necessary, 'public-private partnership (PPP)' is also used to denote general forms of private sector participation, including BOOT/its variants and utility concessions/PPPs.

BOOT projects entail large private capital, a long concession period and multiple stakeholders which in turn, result in an array of major risks, including political and legal risks (Ng and Loosemore, 2007; Merna and Smith, 1996), social risks (Wibowo and Mohamed, 2010; Rebeiz, 2012), technical risks (Özdogan and Birgönül, 2000; Zeng et al., 2007), and financial risks (Xenidis and Angelides, 2005; Lam and Chow, 1999). In this study, financial risks in BOOT for water supply are identified and analyzed. Financial risks occur frequently and affect water infrastructure projects significantly (Ameyaw and Chan, 2015a), given the difficulty in obtaining long-term financing in local currency for water projects (Matsukawa et al., 2003). This creates a mismatch between currencies of financing and revenues. The mismatch, coupled with depreciations of the local currency, has a damaging effect on the sustainability and profitability of BOOT water supply projects (Vives et al., 2006; Lianyu and Tiong, 2005). Tackling problem via pass-through provisions in the contracts has been ineffective because the population is often unable to pay for the associated rate hikes. Financial risks are also associated with higher inflation rates, higher capital costs and lower operating margins or forecasted revenues, and therefore are widely linked to rising project failures (Lee and Schaufelberger, 2014; Vives et al., 2006).

Although there is a a myriad of literature on the general risks in BOOT projects across infrastructure sectors (e.g., Ameyaw and Chan, 2015a; Lee and Schaufelberger, 2014; Rebeiz, 2012; Wibowo and Mohamed, 2010; Ng and Loosemore, 2007; Zeng et al., 2007), there are limited studies on, and hence a less understanding of, financial risks affecting water projects especially in developing countries (Organisation for Economic Co-operation and Development, OECD, 2009). Developing countries are associated with higher risks resulting from unfavorable local conditions, such as macroeconomic factors, tariff sustainability, user willingness to pay, legal frameworks, political factors, institutional capacity and fiscal space (Vives et al., 2006; Matsukawa et al., 2003). These issues influence conditions of investment and private sector's investment decision-making. A review of literature revealed three prominent studies focused upon financial risks in BOOT projects (Xenidis and Angelides, 2005; Wang et al., 2000; Lam and Chow, 1999) but these did not consider financial risks in water BOOTs. This explains a paucity of understanding regards the risks affecting water projects (OECD, 2009) and also sheds some light on why project structures often fail to match prevailing risks (Vives et al., 2006). Moreover, Cheung and Chan (2011) showed that important risks faced by privatised water projects differ from those encountered in transportation and power projects. This suggests a need for a water sector-specific investigation of risks.

[Insert Table 1]

BOOT water supply projects partly face financial risks to design and construct due to the sector's challenging characteristics which differentiate it from other infrastructure sectors. , These characteristics result from the following (Ameyaw and Chan, 2015; see Ameyaw and Chan (2013) for discussion):

- Water infrastructure projects are associated with huge initial capital, lengthy payback periods and lower rates of return;
- Water assets are highly specific and immobile (with approximately 80% fixed underground);
- Critical political and social implications of water services include underpricing and public resistance to private participation; and

- Water utilities tend to be natural monopolies with a limited possibility for competition.

These attributes could explain the difficulties encountered Failure to carefully identify, prioritize, and mitigate them often result in problems in project development and operation/maintenance (Cuttaree, 2008; Vinning et al., 2005). Several cases of distressed/disputed, terminated, or initially unsuccessful BOOT water supply projects have been reported, including the Beijing No. 10 Water Scheme, the Chengdu No. 6 Water Plant B, and the 9th Shen Yang Water Plant in China; the Thu Duc Water Plant in Vietnam; the Bogota Treatment Plant in Columbia; the Tampa Bay Desalination Plant in Florida, USA; and the Sonia Vihar Water Plant in India (Zhang and Biswas, 2013; Barnett, 2007; Hall and Lobina, 2006; Vinning et al., 2005). The lack of understanding and adequate assessment and management of inherent risks are notable root causes of failure on BOOT projects (Lee and Schaufelberger, 2014; Li and Zou, 2011; Cuttaree, 2008). For example, Aguas del Tunari withdrew from the US$2.5 billion, 40-year water utility concession in Cochabamba, Bolivia following violent protests partly brought about by failure to assess the public's willingness to pay higher tariffs (Cuttaree, 2008)[3].

In order to investigate the important financial risks associated with BOOT water projects, a questionnaire survey was conducted on the Nungua Seawater Desalination Plant (NSDP) project, Ghana. The objectives were to:

1. Identify and assess critical financial risks associated with BOOT water supply projects. Perceptual rankings are gathered from a targeted team of expert participants working on the NSDP project.
2. Conduct an evaluation of the financial risk level of the NSDP project. By using the fuzzy synthetic evaluation (FSE) method, an aggregated index (score) is generated representing the perceived financial risk level of the BOOT project.

Perceptual data were collected about the NSDP project through a questionnaire survey. The FSE method was used to represent and model the experiential knowledge of key project participants and address the fuzziness of their expert judgments. The project's description and the FSE were introduced in the research methods section. Awareness and understanding of the critical financial risks on the NSDP would enable management to take appropriate risk mitigation strategies to reduce project risk level and ensure a successful project delivery.

Financial risk

The term 'financial risk' has variations, as different authors include various factors in their risk lists. Lam and Chow (1999) included counter party, defective products, force majeure, slow progress of works and sovereign risks, while Xenidis and Angelides (2005) included risks such as bankruptcy, prolonged negotiation, lack of guarantees, and rate of return restriction. For this research, the definition of financial risk in BOOT projects proposed by Xenidis and Angelides's (2005) was adopted, namely events that "negatively impact on the cash flows of the financial plan in a way that endangers [a] project's viability or limits its profitability" (p. 433). This research considers only risks of an economic nature.

Research methods

To achieve the research objectives, four iterative stages were undertaken: (1) a background review of the FSE tool for analysis; (2) a review of literature and project documentation to identify the relevant financial risks associated with BOOT water supply projects; (3) a questionnaire survey with a team of participants to assess the risks shortlisted in step two. The participants included developers/promoters, consultants and government representatives; and (4) an analysis of survey data using the FSE technique, which generated a numerical aggregated score to represent the perceived risk level of NSDP.

Mathematical tool for analysis: Fuzzy set, and FSE

Selecting a mathematical tool for assessing risks is influenced by the nature of the problem and the purpose of analysis. During the early stages of BOOT projects, risks should be identified to aid risk planning and management (Boussabaine, 2014). However, given limited project data and information during this stage, the risk identification process draws upon qualitative risk analysis which involves prioritizing risks for further analysis or action by assessing their potential impact on the project (Project Management Body of Knowledge®, 2008). This condition is considered a qualitative multicriteria analysis problem.

Fuzzy set theory is suitable for qualitative multicriteria analysis because of its capability to resolve or analyze inaccurate and complex decision problems that result from partial and imprecise information that characterize real projects (Boussabaine, 2014; Li and Zou, 2011; Tah and Carr, 2000; Boussabaine and Elhag, 1999). The fuzzy set approach has a rigorous quantitative mathematical theory (Chen and Hang, 1992) that enables systematic processing of qualitative and imprecise information (Khatri et al., 2011). A risk in a fuzzy environment has sets of values that are described by linguistic terms. These qualitative linguistic terms can be expressed numerically by fuzzy sets. Each set is characterized by a membership function ranging between [0, 1], where 0 represents a non-member~~,~~ and 1 denotes a full member. FSE is one application of the fuzzy multicriteria decision-making techniques considered suitable for this research (Hsiao, 1998).

A major advantage of FSE is that the analysis does not require a statistically significant sample size (Li et al., 2000; Ameyaw and Chan, 2015b). The input data in FSE analysis are based on experts' perceived value judgements. FSE synthesizes various individual elements of an evaluation into an aggregated index (Khatri et al., 2011). The simplicity of the FSE is that experts' judgements are required for only the sub-criteria (lower-level attributes), whose membership functions are used to derive the membership functions of the upper-criteria (higher-level attributes). This alleviates the need for a complicated questionnaire design.

Further, given its theoretical basis in fuzzy set theory (Zadeh, 1965), the FSE approach to risk assessment extends to subjective and uncertain phenomena (Boussabaine and Elhag, 1999); Fuzzy set theory was originally developed to handle these concepts with ease (Jato-Espino et al., 2014). Subjectivity stems from unavailable and incomplete information surrounding risks and the project itself, and the partial ignorance of decision makers (Sadiq and Rodriquez, 2004). The decision maker is unable to provide a precise numerical definition regards the degree of exposure of the project to risks. Hence, the individual and collective impact levels of evaluated risks on the project remain uncertain. The extent of subjectivity and uncertainty in risk criticality assessment are modeled by linguistic values of a fuzzy nature, such as not critical, very low criticality, moderate criticality, and high criticality (see Table 5). Linguistic values provide a means to model "human intolerance for imprecision by encoding decision-relevant information into labels of fuzzy set" (Boussabaine and Elhag, 1999). The estimate of these linguistic values is frequently based on the experience and know-how of the decision maker from similar past projects and his/her knowledge on the present project. These linguistic values are defined to suit the project context. In this study, a common language to describe risk criticality is proposed (Table 5) to ensure consistent evaluation and quantification of the risk index (Tah and Carr, 2000). The linguistic values are defined in a manner that enables an aggregation of all risk impacts to generate an overall measure of the project's (financial) risk level. These linguistic values are used to derive the membership function (or single-factor evaluation vector) of each risk factor and the project risk level based on the collective judgments of the expert participants.

[Insert Table 2]

Some applications of the FSE technique in different fields are summarized in Table 2. The table shows the extensive application and versatility of the method for modeling and decision-making processes in practical and complex multicriteria problems, including damage stage assessment of concrete structures (Liang et al., 2001), risk-based decision making (Sadiq et al., 2004), supplier selection decision-making (Pang and Bai, 2013) and urban infrastructure performance analysis (Khatri et al., 2011). Its applications establish the capability of the FSE to address qualitative multicriteria decision problems to arrive at useful decisions by modeling subjectivity and uncertainty in human experience and behavior (Boussabaine, 2014). In this regard, the authors aim to analyze financial risks in a BOOT water supply project and to predict the risk index of the project based on the experiential judgments of key project stakeholders. The risk index will depict the financial riskiness (risk level) of the project (i.e., 'not risky', 'moderately risky' or 'risky').

Review of literature and project documentation

Table 1 illustrates previous studies that had a specific focus on identification of financial risks and include the influential works of Lam and Chow (1999), Wang et al. (2000), and Xenidis and Angelides (2005). Lam and Chow (1999) surveyed financial risk variables at five phases of the BOT model in Hong Kong, namely: pre-investment, implementation, construction, operation and transfer. They elicited the general opinions of respondents regarding the significance of the risks, reporting that fluctuation in interest rate was the most significant variable at the pre-investment phase, whereas design deficiency and time overrun were highly significant at the implementation stage. Although the study of Lam and Chow enhances our understanding of financial risks in BOOT projects, it is time-bounded and hence, the significance of the reported risks may have declined or gained prominence over time. Given the study's focus on BOOTs in general, the important risks may not reflect those faced by water projects. Wang et al. (2000) surveyed practitioners' perception on the criticality of foreign exchange and revenue risks in BOT power projects. The authors reported that the important risks, in order of criticality, are tariff adjustment, dispatch constraint, foreign exchange, and financial closing risk. Drawing on the literature, Xenidis and Angelides (2005) provided a review and discussion regards checklist(s) of financial risks in general BOT infrastructure projects. However, the adopted research method was not designed for evaluating and prioritizing the risks. An alternative approach will be to subject the identified risks to a larger rating panel or test the risks on an actual project.

The review also included previous studies that reported on general risks in water-based BOOTs and utility PPPs (e.g., Şentürk et al., 2004; Zeng et al., 2007; Wibowo and Mohamed, 2010; Choi et al., 2010; Vives et al., 2006). Şentürk et al. (2004) examined a list of major risks associated with implementation of the Izmit Domestic and Industrial Water Supply BOT project in Turkey. Water sale price, land acquisition, return on equity, and determination of optimum operation period were some of the key risk issues reported. Zeng et al. (2007) carried out risk assessment/prioritization in BOT water supply projects in China based on eight risk categories, namely: political, bid and negotiation, economic, construction, operating, policy and legal, credit and force majeure. Regarding commercial risks, interest rate fluctuation, price variation of water resources, and foreign exchange rate volatility were found be critical. Research studies pertaining to risks associated with general BOOT projects in other infrastructure sectors (power/energy and transport) have also been reported (Yang et al., 2010; Lee and Schaufelberger, 2014; Rebeiz, 2012). In Ghana, literature relating to risk identification and allocation in utility water PPPs was reviewed (Ameyaw and Chan, 2013, 2015a, b). Ameyaw and Chan (2015a) presented a risk prioritization framework for water PPPs by using the Delphi method. Foreign exchange rate, corruption risk, water theft, non-payment of bills, and political interference were reported as the five most significant risks while expropriation, climate change, raw water scarcity, political violence and demand risks were found to be least critical.

The NSDP project was also analyzed to ascertain possible financial risks that may face it. The analysis was conducted through primary documentary review of contract documentation (concession agreement) and secondary documentary analysis of industry and professional reports, and newspaper articles. Merna and Smith (1996) noted that a concession agreement affords a useful source of information because it provides the basis of a long-term contract between private and public parties. It also identifies the risks and responsibilities linked to the financing, construction, operation/maintenance and revenue packages of a BOOT project. Table 3 reports upon the risks identified from related literature.

[Insert Table 3]

A preliminary list of 25 financial risks related to BOOT water supply projects in general and unique to Ghanaian environment was prepared following the literature review and documentary analysis (Table 3). Prior to preparing a questionnaire, the shortlisted risks were presented to a consultant (at Ghana's PPP Advisory Unit) for review and validation. The consultant was invited because of his direct involvement in the preparation of the concession agreement and risk-related negotiations, and has hands-on experience and specific knowledge on the NSDP. He also has 30 years of experience of Ghana's water industry and was available and willing to review the risks. Although the authors initially sought inputs from three practitioners, the other two indicated their unavailability. However, a review from the above-mentioned consultant is deemed sufficient given his participation, experience and knowledge on the project. The consultant was asked to indicate the important financial risks that apply to the NSDP project. Of the 25 risks short listed, 18 were verified and confirmed as 'significant' to the NSDP. Seven risks (unpaid bills by customers, supporting utilities risk, design deficiency, land unavailability, water theft by consumers, high bidding costs, and technology risk) were removed from the checklist, because they were not significant for the NSDP. Table 3 presents and compares the risks in the NSDP with those reported in the literature. It suggests that the shortlisted risks facing the project compares well with previously reported risks. The 18 risks were then formulated into a questionnaire for a survey.

Questionnaire survey

Project background – Nungua Seawater Desalination Plant (NSDP)

A questionnaire survey was conducted on the NSDP[4] to measure how the project participants perceive the relative significance of the identified risks associated BOOT water supply projects in Table 3. This project is located in Ghana's capital city Accra and is selected because it is the first large-scale water supply project tendered on a long-term BOOT contract in the country. Therefore, the project provides a good example to further our understanding of risks. The NSDP project is a 25-year water purchase agreement between Ghana Water Company Limited (GWCL) and Befesa Desalination Development Ghana Ltd. (Befesa–Ghana: a consortium between Abengoa Water and Daye Water Investment). The NSDP project was finalized financially in November 2012 with a US$88.7 million 12-year loan from the Standard Bank of South Africa, while the remaining US$38.1 million came from stakeholder loan and equity. This arrangement resulted in a debt-to-equity ratio of 70:30 (Global Water Intelligence: GWI, 2012). This US$126.80 million project involves the design, construction, operation and maintenance of a 60,000 m^3/day desalination plant with a water rate of US$1.36/$m^3$. The construction duration of the NSDP project is 24 months. GWCL is the off-taker and is supported by a guarantee from the Ministry of Finance and Economic Planning (GWI, 2012; GWCL and Befesa Ghana, unpublished Water Purchase Agreement on NSDP, 2012).

Survey and participants for risk assessment

A risk assessment team of seven project participants having sufficient background knowledge of the PPP projects environment in Ghana and especially specific knowledge of and information on the NSDP project was created to assess the identified risks. This approach is acceptable and widely used in risk management research (e.g., Ng and Loosemore, 2007; Thomas et al., 2006). The PPP Advisory Unit (which manages and oversees public-private partnerships and serves as a centre of expertise) was approached to nominate participants with a direct involvement in the NSDP. Although the size of the risk assessment team is small, reliable assessment results is anticipated because the sample included top-level management officials with direct decision making roles in the project. The seven participants were involved in the preparation of contract documentation, risk-related negotiations and management of the NSDP.

Table 4 summarizes the participant's profiles; two from the client organization (GWCL), two from the local partner of the project (Hydrocol Ltd.), two from the PPP Advisory Unit, and one from the utilities regulator (Public Utilities Regulatory Commission (PURC). Although participants A and E have seven and four years of industry experience, respectively, they were deemed fit to participate in the survey because of their direct involvement in and subsequent knowledge of the NSDP project. The authors were not able to secure lenders' participation given their location outside Ghana and time limitation. There was however, participation from a local partner, Hydrocol Ltd. The participants were contacted ahead of time to explain to them the requirements and the questionnaire instrument which was then sent at a later date. The questionnaire was delivered in person, thereby allowing for clarification of any additional issues respondents might have. The questionnaire was then collected after two weeks.

[Insert Table 4]

As part of the assessment exercise, a questionnaire instrument was prepared based on the 18 risk factors for the purpose of eliciting the participants' opinions on these risks. The questionnaire was designed: (1) to gather perceptual rankings of the critical financial risks from persons with direct experience with the NSDP project; and (2) to measure NSDP's financial risk level. Part I of the survey instrument extracted contextual information on the respondents and their organizational affiliations, including their respective positions, years of water industry experience, and role in with the NSDP project. The rationale behind the risk assessment exercise and the contributions of participation in the research was clearly elucidated upon to all respondents (Dillman et al., 2008). Part II asked each project participant to independently rate the "criticality" of the shortlisted risks based on their perception and direct experience with / knowledge of the water project. Criticality is assumed as the joint effect of the likelihood of occurrence and the impact of the corresponding risk (Thomas et al., 2003). Wang et al. (2000) and Thomas et al. (2003) have used the criticality criterion for measuring BOOT project risks. A seven-point scale ranging from "Not critical" (NC) to "Extremely critical" (EC) was adopted for assessing risk criticality (see Table 5). These descriptive linguistic variables provided the participants with flexibility and the ability to measure the risks objectively and reliably (Shang et al., 2005). They also helped to generate rankings of the risks and their membership function sets (Chan, 2007) to quantify the criticality levels of the risks as well as and the overall risk index of NSDP. Based on the perceived criticality ratings of the risk assessment team, the mean criticality index, standard deviation, and criticality levels of the risks were calculated. The means criticality scores were calculated using Eq. (4) as follows. Standard deviation values were calculated using *SPSS version 21.0* statistical package 21.0 (Pallant 2005). Additionally, a fuzzy based analysis on the risk factors was conducted to measure the risk level of the project.

[Insert Table 5]

Evaluation of survey results and findings

Results obtained from FSE analysis

Feedback from the risk criticality rating exercise was collated and analyzed. The FSE was adopted to quantify the impacts of the risks and to predict the financial risk level (FRL) of the case project. Figure 1 illustrates the operationalization of the fuzzy methodology adopted. The analysis provides a reliable and systematic method for evaluating and prioritizing the critical risks associated with the project and consequently quantifying its risk index, in order to enable a proactive project risk management. To assess the overall FRL of the NSDP project, both the weighting and membership functions of each risk factor were derived. Both functions of the risks were based on the ratings of the project participants according to the predefined descriptive linguistic variables. A fuzzy operator (discussed in step 4 below) was employed to process the weighting and membership function sets. FRL of the NSDP project contained 18 risks; thus, the multilevel and multifactorial fuzzy models (Li et al., 2000; Hsiao, 1998) were used to calculate the membership functions of the risk factors, to form the single-factor evaluation matrix ***(R)*** (or fuzzy relational matrix in Fig.1) and to compute the single-factor evaluation vector ***(D)***. In this regard, the FRL was derived by defuzzifying ***D*** through a set of indices, which defined the extent of the risk impact. The major steps in the fuzzy risk assessment process are detailed as follows.

[Insert Fig. 1]

Step 1: Establish the set of basic risks and letter grades for evaluation

The basic risks that affect the project are as follows (refer to Table 5): $\mathbf{r}_1$ = bankruptcy of consortium member(s), $\mathbf{r}_2$ = unfavorable economy of the host country, $\mathbf{r}_3$ = tariff adjustment uncertainty, and $\mathbf{r}_{18}$ = unfavorable economy of the country of the main stakeholders. Therefore, $\boldsymbol{\pi} = \{\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \ldots, \mathbf{r}_{18}\}$. The set of qualitative classes (or linguistic variables) for the evaluation is as follows: $\boldsymbol{v}_1$ = 'not critical' (NC), $\boldsymbol{v}_2$ = 'very low criticality' (VLC), $\boldsymbol{v}_3$ = 'low criticality' (LC), $\boldsymbol{v}_4$ = 'moderately critical' (MC), $\boldsymbol{v}_5$ = 'critical' (C), $\boldsymbol{v}_6$ = 'very critical' (VC), and $\boldsymbol{v}_7$ = 'extremely critical' (EC). Therefore, $\mathbf{V} = \{\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{v}_4, \boldsymbol{v}_5, \boldsymbol{v}_6, \boldsymbol{v}_7\}$. These linguistic variables were used to maximize the extensive knowledge of industry respondents, thereby minimizing subjectivity and vagueness in human perception, and to compute the linguistic variables for the risk level in the NSDP project.

Step 2: Compute the membership function sets and impact scores of risks

The membership function set $\left(MF_{r_i}\right)$ of each risk can be derived by using fuzzy mathematics based on the value judgment of the respondents. Given the seven linguistic variables in Step 1, the membership function set of a particular risk r_i is obtained through Equation (1) (Chan, 2007; Liu et al., 2013) as follows:

$$MF_{r_i} = \frac{a_{i1}}{v_1} + \frac{a_{i2}}{v_2} + \ldots + \frac{a_{in}}{v_n} = \frac{a_{i1}}{extremely\, low} + \frac{a_{i2}}{very\, low} + \ldots + \frac{a_{in}}{extremely\, high}, \qquad (1)$$

where a_{ik} is the membership grade and a_{ik}/v_k signifies the relationship between v_{ik} and its *MF* but not fractions. Thereafter, a single-factor evaluation vector for a risk r_i is obtained (Li et al., 2000) as follows:

$$MF_{r_i} = \left(a_{i1,}\ a_{i2,}\ \ldots,\ a_{in}\right). \qquad (2)$$

Consequently, the single-factor evaluation vectors of all the 18 risks are expressed in a fuzzy relational matrix as follows:

$$R = \begin{vmatrix} MF_{r_1} \\ MF_{r_2} \\ MF_{r_3} \\ MF_{r_4} \\ MF_{r_5} \\ MF_{r_6} \\ MF_{r_7} \\ MF_{r_8} \\ MF_{r_9} \\ MF_{r_{10}} \\ MF_{r_{11}} \\ MF_{r_{12}} \\ MF_{r_{13}} \\ MF_{r_{14}} \\ MF_{r_{15}} \\ MF_{r_{16}} \\ MF_{r_{17}} \\ MF_{r_{18}} \end{vmatrix} = \begin{vmatrix} a_{11} & a_{12} & \cdots & a_{17} \\ a_{21} & a_{21} & \cdots & a_{27} \\ a_{31} & a_{32} & \cdots & a_{37} \\ a_{41} & a_{42} & \cdots & a_{47} \\ a_{51} & a_{52} & \cdots & a_{57} \\ a_{61} & a_{62} & \cdots & a_{67} \\ a_{71} & a_{72} & \cdots & a_{77} \\ a_{81} & a_{82} & \cdots & a_{87} \\ a_{91} & a_{92} & \cdots & a_{97} \\ a_{101} & a_{102} & \cdots & a_{107} \\ a_{111} & a_{112} & \cdots & a_{117} \\ a_{121} & a_{122} & \cdots & a_{127} \\ a_{131} & a_{132} & \cdots & a_{137} \\ a_{141} & a_{142} & \cdots & a_{147} \\ a_{151} & a_{152} & \cdots & a_{157} \\ a_{161} & a_{162} & \cdots & a_{167} \\ a_{171} & a_{172} & \cdots & a_{177} \\ a_{181} & a_{182} & \cdots & a_{187} \end{vmatrix} = \begin{vmatrix} 0.00 & 0.00 & 0.00 & 0.00 & 0.33 & 0.33 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.14 & 0.57 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.14 & 0.14 & 0.43 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.14 & 0.29 & 0.29 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.57 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.43 & 0.57 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.67 & 0.17 & 0.17 \\ 0.00 & 0.00 & 0.00 & 0.17 & 0.50 & 0.00 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.71 & 0.14 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.29 & 0.57 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.40 & 0.20 & 0.00 & 0.40 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.14 & 0.29 \\ 0.00 & 0.00 & 0.17 & 0.17 & 0.33 & 0.00 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.57 & 0.29 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.57 & 0.29 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.43 & 0.14 & 0.14 \end{vmatrix} \qquad (3)$$

After deriving the membership function set of each risk in Equation (3), an index suggested by Chen (1998) was used to compute the 'mean criticality' (Z_i) of each risk to determine its rank and degree of criticality to the project. Criticality index of each risk is obtained by defuzzificating its membership function set using Equation (4). The reason for using Equation (4) is that the risk criticality rating has drawn on the expert judgment of the respondents using linguistic values (which can be considered an ordinal measurement system) and is representative of the risk assessments of the respondents.

$$Z_i = a_{i1}k_1 + a_{i2}k_2 + \cdots a_{in}k_i = \sum_{i=1}^{\circ} a_{ij}k_i \qquad (4)$$

where

Z_i denotes the mean criticality score for the ***i***th risk (a higher index indicates greater potential impact of the risk on the project),

a_{ij} represents the degree of membership, and

k_i represents a variable of varying impact level of a risk. The seven linguistic grades in Step 1 ($\boldsymbol{v}_1$, $\boldsymbol{v}_2$, $\boldsymbol{v}_3$, $\boldsymbol{v}_4$, $\boldsymbol{v}_5$, $\boldsymbol{v}_6$, and $\boldsymbol{v}_7$) with the corresponding numeric grades (1, 2, 3, 4, 5, 6, and 7, respectively) assigned to them described the impact levels of the risks. The numeric grades were used to defuzzify the membership function sets of the risk factors.

The third column of Table 6 shows the computation of Z_1 to Z_{18}. Arranging the Z_i values in decreasing order of magnitude can determine the impact levels and ranks of the risk factors. Consequently, the mean criticality score of a factor can be included in any of the seven bands of the transformed rating scale in Table 4. Risks with Z_i values ≥ 4.51 are considered critical. Based on the transformed measurement scale in Table 4, a risk factor with Z_i values < 4.51 belong to NC, VLC, LC, or MC.

[Insert Table 6]

Step 3: Compute the weighting functions of the risks

The weighting function w_i denotes the relative criticality of a risk evaluated by the project participants. In this research, the normalized mean method used (Yeung et al., 2007) for determining weighted key performance indicators for construction partnering projects. The weighting of each risk is derived by normalizing its mean criticality index through Equation (5) (i.e., dividing each index by the sum of the indexes). The weighting vector must also satisfy the following normality condition (Li et al., 2000):

$$w_i = \frac{Z_i}{\sum_{i=1}^{\circ} Z_i}, \quad 0 < w_i < 1, \text{ and } \sum_{i=1}^{\circ} w_i = 1 \tag{5}$$

Therefore, the normalized weighting function set is

$$W_{r_i} = \left(w_{r_1},\ w_{r_2},\ \ldots,\ w_{r_{18}}\right) \tag{6}$$

The fifth column of Table 5 presents the weighting functions of the risks. Figure 2 further illustrates the weighting functions.

[Insert Fig. 2]

Step 4: Determine the fuzzy vector of the project risk level

From the fuzzy evaluation matrix R in Equation (3) and the weighting function set W in Equation (6), the following equation is employed to establish the fuzzy synthesis evaluation result, namely, the evaluation vector:

$$\boldsymbol{R} \circ \boldsymbol{W} = \boldsymbol{D}, \tag{7}$$

$$D = \frac{d_1}{v_1} + \frac{d_2}{v_2} + \ldots + \frac{d_7}{v_7} \quad (0 \le d_k \le 1), \tag{8}$$

where d_k is the membership function of the denominator v_k with respect to the fuzzy evaluation vector $D = (d_1,\ d_2,\ \ldots,\ d_7)$. The symbol "$\circ$" refers to the fuzzy operation, which is performed by various mathematical functions (Lo, 1999). The accuracy of the assessment results depends on a careful selection of the appropriate function to process Equation (7). In the present study, the $M(\bullet,\ \oplus)$ (weighted mean) function is selected. This function is defined as follows (Hsiao, 1998):

$$d_k = \min\left\{1,\ \sum_{i=1}^{\circ} w_i a_{ij}\right\}, \qquad j = 1, 2, \ldots, n. \tag{9}$$

Li et al. (2000) and Hsiao (1998) posited that when the weighting w_i satisfies the normality condition $\sum_{i=1}^{\circ} w_i = 1$, the "$\oplus$" degenerates to $\mathrm{M}(\bullet, +)$; thus,

$$d_k = \sum_{i=1}^{\circ} w_i a_{ij}, \qquad j = 1, 2, \ldots, n. \tag{10}$$

In this regard, Equation (10) accounts for the influences of all the risks, which is suitable for evaluating the contribution of risks from a general perspective (Hsiao, 1998).

Therefore, by using Equation (8), the result of the fuzzy evaluation vector of the project risk level becomes

$$D = \frac{0.00}{\text{extremely low}} + \frac{0.00}{\text{very low}} + \frac{0.01}{\text{low}} + \frac{0.19}{\text{moderate}} + \frac{0.36}{\text{high}} + \frac{0.25}{\text{very high}} + \frac{0.19}{\text{extremely high}} \tag{11}$$

$$= (0.00,\ 0.00,\ 0.01,\ 0.19,\ 0.36,\ 0.25,\ 0.19).$$

Step 5: Defuzzify the fuzzy vector of the project risk level

After establishing the fuzzy evaluation vector in Step 4, the FRL of the NSDP project was quantified by defuzzifying its membership function set through Equation (12). The risk score of this project can be included in any of the seven bands of the risk levels in the last column of Table 5, which range from extremely risky (ER) to not risky (NR).

$$Z_{\text{FRL}} = \sum_{k=1}^{\circ} d_k \cdot k = 0.00\times1 + 0.00\times2 + 0.01\times3 + 0.19\times4 + 0.36\times5 + 0.25\times6 + 0.19\times7 = 5.4312 \tag{12}$$

The key assumption of the aforementioned fuzzy-based analysis is that all seven respondents are experienced in BOOT projects and highly familiar with the study project (Table 3) and thus, the reliability of their judgments is ensured. Notably the approach presented above analyses the influences of risks and determines a project's risk level but the management or mitigation of the risk items is beyond the scope of this research.

Reliability analysis

Table 7 provides important information termed "project risk level (score) if risk item is deleted." This follows measurement scales' reliability analysis (see Pallant, 2005). This information measures the effect or contribution of each risk factor to the overall risk score (index) of the case project. The risk scores are the scores of the overall risk level of the NSDP project if the corresponding risk is removed from the calculation of the fuzzy model. Therefore, the risk scores (which depict the project risk level) are based on 17 risk factors, excluding the corresponding risk factor. By comparing these risk level scores with the overall risk level score (5.43) obtained in Equation (12), any risk factor that effectively contributes to the FRL of the NSDP project should have a corresponding score ≤ 5.43. By contrast, a risk factor that does not contribute will have a risk level score > 5.43. However, this condition is not violated; thus, each risk factor effectively contributes to the financial risk level of the NSDP project. None of the risks should also be excluded from the 18-factor risk list. Also, Table 7 implies that the items in our measurement scale measured the same underlying construct and that the scale is reliable and has a good internal consistency.

[Insert Table 7]

5. Discussion

The assessment results provide two major conclusions. First, the global risk level of the NSDP project is 5.43, which suggests that the 18 risks collectively have a critical impact on the cash flow and viability of this project. Therefore, the NSDP project can be described as financially risky (R) (Table 5). This conclusion and the results clearly support the findings of previous researchers that BOOT (water supply) projects are vulnerable to financial risks (Barnett, 2007; Zheng et al., 2007; Vives et al., 2006; Lianyu and Tiong, 2005; Xenidis and Angelides, 2005; Lam and Chow, 1999). Therefore, effective mitigation measures should be implemented to neutralize the adverse consequences of the assessed risks. Second, all the financial risk factors are risky because their mean criticality ratings, which range from 5.14 ('critical') to 6.00 ('very critical'), are greater than the 4.51 threshold. Table 6 shows that eight risks are included in the 'very critical' band, while the remaining 10 risks are found in the 'critical' band. The top five risks are briefly discussed here because they have 'very critical' scores and because of the space limitation in this paper. The discussion is supported with references to similar examples to enrich our understanding of the risks.

The bankruptcy of consortium member(s) is assessed as the most critical risk with a 'very critical' rating (Table 6). This risk informs public clients that the progress of a project can be jeopardized in case the concessionaire files for bankruptcy. This information is critical because a possible bankruptcy risk may or may not necessarily relate to the project in question but to other business operations of the stakeholder(s) (Xenidis and Angelides, 2005). For example, in the troubled Tampa Bay Seawater Desalination Plant, the Covanta Tampa Construction was awarded a construction contract and a 30-year concession to operate and maintain the facility. Vinning et al. (2005) explained that because of the poor and mistrustful relationship between Covanta and Tampa Bay Water, the former filed for bankruptcy in October 2003; the primary reasons include the energy crisis in California, which affected the cash flow of Covanta (Barnett, 2007), and to stop Tampa Water from terminating the partnership and replacing Covanta (Vinning et al., 2005). Ultimately, the risk adversely affected the project in terms of cost and time because Tampa Water had to find another firm to replace Covanta and to address the treatment problems of the plant (Wall, 2013; Barnett, 2007).

The unfavorable economy of the host country reminds public–private stakeholders that the economic environment where a BOOT water scheme is to be implemented has a significant influence on the eventual success of the project (Xenidis and Angelides, 2005). This risk ranks second with a 'very critical' rating. This score indicates that the expert respondents are highly concerned with an unstable economy with structural deficiencies, an immature and undersized stock market, foreign exchange fluctuation, currency devaluation, and fluctuation in interest and inflation rates, as reflected in Ghana (Ameyaw and Chan, 2015a) and many other developing countries. The implication of this risk is that the host government may fail to meet agreed guarantees, honor its payments under the contract, or funding availability and cost slippage problems may occur; thus, demand for water product may decline (Lee and Schaufelberger, 2014). In the aftermath of the 1997 East Asian financial crisis, the Taiwanese currency was devalued by approximately 30%, which resulted in a huge cost overrun of roughly US$500 million in the Taiwan High Speed Rail project (Lee and Schaufelberger, 2014).

The uncertainty in the tariff adjustment of water products hints that the respondents are concerned with the commitment of the current or future government to accept upward adjustments of the operating tariff in case of unexpected macroeconomic conditions (e.g., high inflation rate, currency devaluation, foreign exchange risk, etc.) during the 25-year concession period. Such conditions are frequently beyond the control of the concessionaire. In BOOT projects in China, tariff adjustment is the most critical risk because the government insists on tariff renegotiation on an annual basis; a government price control authority must also approve the adjustment (Wang et al., 2000, p. 202). The 'very critical' rating of this risk corroborates the findings of Choi et al. (2010) and Wibowo and Mohammed (2010) that tariff adjustment risk has damaging outcomes on private investments in water projects in developing countries. This risk results in low operating margins and poor service levels, as well as renders the revenue flow and profit levels of a project unpredictable; thus, the long-term sustainability of the concessionaire and the project itself is threatened.

The rate of return restriction risk (profitability) reflects the decision of the current or future government to restrict or impose a cap on the rate of return of the investment of the project (e.g., if the returns of the investors are deemed excessive) (Xenidis and Angelides, 2005). Being the first capital-intensive BOOT water supply project in Ghana, the respondents are concerned that a future government may retain a rate of return for the investment. Experience shows that rate of return restrictions frequently occur in BOOT projects; for example, foreign investors in China have raised concerns regarding the 15% cap of the authorities on the rate of return of private investment projects (Lee and Schaufelberger, 2014; Wang et al., 2000). Therefore, imposing caps on the rates of return of projects has immense consequences, as reflected by the 'very critical' score of the risk. These consequences include a reduction in the viability of a BOOT project because the cap limits the capability of investors to balance project risks with corresponding returns (Wang et al., 2000), as well as proves difficult in attracting investors or finances for infrastructure projects, as experienced in the Laibin B Power Plant in China (Lee and Schaufelberger, 2014).

The availability problems of private sector capital reminds both the government and private participants of the difficulties in raising sufficient finances on time for water infrastructure projects, particularly in developing countries. This difficulty is attributed to the reluctance of foreign donors and financial institutions to provide sizeable funds because of the perceived high risk profiles of these countries (Vives et al., 2006; Wang et al., 2000). With a 'very critical' score, the respondents are concerned with funding unavailability until the completion of the water treatment plant construction. This concern stemmed from the event that when the NSDP project was first awarded to a Norwegian developer (Aqualyng) in 2008, the developer failed to raise finances from the international financial market, which led to the termination of the project in 2010 (GWI, 2012). In another example, a consortium of Mitsubishi and Anglian Water failed to implement the Beijing No. 10 Water Treatment plant due to inability to raise debt financing as a result of inadequacies in the financing policies and regulatory systems of China (Zhang and Biswas, 2013). The Chinese government imposes stringent capital requirements and limited financing routes on private firms and strictly regulates the approval process for the principal financing source – bank loans (Li and Zou, 2011). This finding supports the results of previous studies (Li and Zou, 2011; Wang et al., 2000; Tiong, 1990) which demonstrated that a major aspect of the successful execution of the BOOT model is raising financing. Therefore, financing risk requires innovative approaches to the financing and security of private investments, such as providing government guarantees (foreign exchange guarantees, interest subsidies, revenue guarantees, tariff guarantees, off-take agreements, tax exemptions, and debt guarantees), sound contractual structures, and fair risk allocations.

The proposed fuzzy methodology provides useful implications for practitioners. This methodology is more suitable for the early phase of a BOOT or PPP project, as used for prioritizing major risk events that require further analysis or action by management and for measuring the NSDP's risk level. This process is important because it allows the determination of risks for a detailed analysis and pricing in the later stages of a project. The proposed methodology also has the advantage of minimizing subjectivity associated with the assessment of risks by the experts. By using linguistic variables and appropriate fuzzy mathematical algorithms, the weightings and memberships of all the risks are combined and transformed to reduce imprecision and vagueness (Lo, 1999). Therefore, the proposed method can improve the accuracy of the risk evaluation results.

Limitations and further work

The main limitations of this research lie in the perception-based assessment of a set of financial risks in a single case study and the small sample size of the risk assessment team of project participants. The risk list may not be representative of all BOOT water supply projects risks in the Ghanaian project environment. However, being the first BOOT project in the water sector, it is crucial to study it in order to determine the important risk issues. Also, multiple methods, including literature review and project documentary analysis, a discussion to review and validate the shortlisted risks, expert risk rating exercise, and fuzzy set analysis, were used for purpose of research validity. For a single case, the use of seven project participants with direct experience with the project may be considered appropriate. This study's sample size was similar to those of previous analyses. Thomas et al. (2006) and Ng and Loosemore (2007), for example, used six respondents for risk analysis in a single case study. This limitation is further addressed through the careful selection of members of risk assessment team. The selection process was guided by industry/sector expertise, hands-on experience with BOOT procurement, and familiarity with the NSDP project, and top-level officials of the project management team. The third limitation is that this research does not explore the mitigation or management of the identified financial risks as well as their relationship with other project risks.

The above limitations provide avenues for further research to enhance risk management in BOOT projects. Research should be conducted on more project cases to include possible risks missed in this research. Such a study should examine other important risk categories, including political, legal/regulatory, social and operational risks. Here, this research will apply other decision models to risk management in PPP projects; these methods include portfolio decision models (Convertino and Valverde, 2013) and global sensitivity and uncertainty analysis

(GSUA) (Saltelli et al., 2008; Lüdtke et al., 2007). The research will also cross compare results obtained from the fuzzy set theory with portfolio decision methods and GSUA and elaborate on the strengths and weaknesses of the different methods. Related to the above, the third limitation should be addressed by establishing the linkages or relationships among the different project risk categories in order to develop a full understanding of NSDP project's comprehensive risk management program. This will help to achieve and sustain efficiency in managing this and other BOOT projects to realize prescribed objectives.

Conclusions and significance

The research aimed to identify and assess the critical financial risks associated with BOOT water supply projects and to conduct an evaluation of the financial risk level of a selected BOOT water project. The objectives were achieved by conducting a questionnaire survey on the NSDP project in Ghana. A list of financial risks prepared based on review of literature and project documentation were assessed by a team of seven participants with a direct involvement in the project. A total of 18 risks were found to be 'very critical' or 'critical' to NSDP and this has given an insight into the important financial risks faced by large-scale water projects in developing countries. The research suggests the top-five critical risks to water BOOTs as bankruptcy of consortium member(s), the unfavourable economy of the host country, the uncertainty in the tariff adjustment of water products, restrictions on the rate of return, and the availability problems of the private capital.

Results obtained from FSE analysis indicates the NSDP project is financially risky to the project stakeholders. The generated risk index encapsulates effects of all the 18 critical risks identified for the research. All these risks must be the initial focus of public and private sectors if they are to effectively manage the risks associated with BOOT projects. The results further suggest that several of the risks ranked most highly by the participants are directly associated with the economic or financial environment in Ghana. These risks include the unfavorable economy of the host country, availability problems of private sector capital, inflation rate volatility, high construction costs, foreign exchange rate risk, etc. A country's economic environment present significant risks to the infrastructure sector, given that such risks impact on financial structures supporting project sustainability.

The results indicate that the FSE method can be used to evaluate and prioritize risks in BOOT or PPP projects. The method does not always require a statistically significant sample size, and improves the accuracy of assessment results given its ability to effectively handle the subjectivity of experts. Because the input data in FSE analysis are based on experts' perceived judgements makes it suitable for the early phases of BOOT / PPP projects to determine significant risks that require the attention of and detailed analysis by project managers.

The findings are of importance to the development of BOOT and PPP practice. The Ghanaian Government has renewed its commitment to using PPPs for delivery of public infrastructure and services, including water supply. The government has introduced a PPP policy (*Private Participation in Infrastructure and Services for Better Public Services Delivery*) to encourage and attract private sector participation. Currently, about 29 water supply projects are awarded or proposed to be delivered through PPP mode. These projects include major expansion and rehabilitation and greenfield projects (GWCL, 2011). Hence, the number of privatised water supply projects is expected to increase. Over the past decade, two BOOT water projects were initiated and eventually abandoned following a lack of assessment of: (1) public concern over water tariffs and foreign (private) company involvement in public water services delivery resulted in public resistance; (2) corrupt practices in contract award; and (3) unavailability of private capital (Ameyaw and Chan, 2015b). Thus, the BOOT procurement process generates major risks and will not be a mere vehicle for the government to provide bulk water supply but requires effective project risk management. In this process, identification and assessment of risks are useful procedures, given that risks must be identified before they can be assessed and prioritized and subsequently monitored and controlled. By focusing on the first privately-financed BOOT project in the water sector and identifying the critical financial risks in the Ghanaian project environment, the public and private sectors would benefit: (1) private investors/developers become aware of important risks in the NSDP project and similar future projects; (2) local government is able to prepare specific guarantees to counter specific risks raised by this research; and (3) to enable allocation of resources (time, money and human) to appropriate project areas.

Notes:

[1]Contractual arrangements and the characteristics of BOOT or public–private partnership (PPP) projects are discussed in detail by Rebeiz (2012), Delmon (2001), and Merna and Smith (1996). Delmon specifically provided a *commercial and contractual guide for water projects* under PPP contracts.

[2]These contracts tap private sector's management expertise for efficiency improvement and better governance in public water utilities, with service delivery modalities such as service contracts, management contracts, and leases.

[3]The lack of assessment of consumer willingness to pay the higher tariffs resulted from the contract. After the civil unrest, the

Government unilaterally revoked the rate increases. Following this decision, Aguas de Tunari withdrew from the agreement, as performance of the contract requirements was no longer financially viable without the rate increases. The resulting contract dispute went to the International Centre for Settlement of Investment Disputes.

[4]The demand for potable water outweighs supply in the urban centers of Ghana (Ameyaw and Chan, 2013, 2015b). The World Bank revealed that the urban water supply infrastructure funding gap in this country is approximately US$4 billion for the next decade (Foster and Pushak, 2011). To address this imbalance, the Ghanaian government, through the Ghana Water Company Limited (hereafter, GWCL), initiated a BOOT project to develop a major water treatment plant for bulk water supply using seawater as the source.

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Tables

~~**Table 1.** Previous specific studies on financial risks in BOOT projects~~

~~Authors~~	~~Purpose / sector~~	~~Country~~	~~Significant financial risks identified~~
~~Lam and Chow (1999)~~	~~A questionnaire survey to explore the significance of financial risks in BOT projects in general~~	~~Hong Kong~~	~~Interest rate, design deficiency, time overrun, competition, currency exchange restrictions, defective products or facilities.~~
~~Wang et al. (2000)~~	~~An international survey on the criticality of foreign exchange and revenue risks in BOT power projects~~	~~China~~	~~Foreign exchange rate, currency convertibility risk, financial closing risk, dispatch constraint risk, tariff adjustment risk.~~
~~Xenidis and Angelides (2005)~~	~~A review of the literature to identify and categorize financial risks associated with BOT projects in general~~	~~Not applicable~~	~~Bankruptcy, import/export restrictions, high construction costs, lack of guarantees, currency risk, cost overruns, financing risk, loan risk, unfavourable local and international economies, inflation risk, risk of pricing product, high bidding costs, etc.~~

Table 2. Selected previous studies on application of the FSE method

Study	Specific area of application	Summary of application
Liang et al. (2001)	Damage stage assessment of structures	FSE is applied to establish a multiple layer fuzzy model for assessing the damage stage of reinforced concrete bridges. The method is advantageous at assessing damage conditions of existing concrete structures.
Chang et al. (2001)	River water quality analysis	Utilized the FSE methods to determine the water quality conditions of the Tseng-Wen River system in Taiwan. The fuzzy approach is helpful at developing sound water quality management strategies.
Sadiq et al. (2004)	Risk analysis decision-making	FSE-based framework is developed for selecting an optimal drilling waste discharge option.
Li et al. (2005)	Concrete durability assessment	General FSE framework is developed for the evaluation of accelerated concrete durability. The FSE's results are consistent with that of the experimental results.
Lan et al. (2005)	Prototyping process selection	FSE and an expert system are integrated to design a decision support system for selecting suitable rapid prototyping processes. FSE rank orders the alternatives and selects the appropriate prototyping system.
Huang et al. (2008)	Enterprise risk analysis	FSE is embedded in a tabu search algorithm for risk analysis in virtual enterprises. It is used to tackle uncertainty and fuzziness.
Khatri et al. (2011)	Urban infrastructure performance	FSE method is proposed to synthesize performance indicators into an index to assess the overall performance of individual urban infrastructure systems.
Mi et al. (2011)	Environment lodging stress	The study assesses the environment stress lodging for maize, and the overall stress level for various study sites are derived through the FSE method.
Tran et al. (2012)	Manhole inspection	Developed a fuzzy risk ranking model based on fuzzy set and analytical hierarchy process (AHP). FSE is performed to obtain the fuzzy number of final risk rank.
Liu et al. (2013)	Construction risk analysis	A risk assessment model based on the FSE method is proposed for construction drilling projects risk assessment.
Pang and Bai (2013)	Supplier selection	An analytical network process (ANP)-FSE supplier evaluation and selection methodology is proposed, in which FSE is applied to select a supplier alternative.
Ma et al. (2014)	Urban rail facilities	FSE is integrated with AHP to develop an AHP-FSE model for assessing the impact of adverse weather on urban rail transit facilities and to derive the risk level of an evaluation target.
Ameyaw and Chan (2015b)	Risk allocation decision-making	A fuzzy-based risk allocation model for the assignment of risks between the public and private parties in PPP projects.

Table 3. Identification and comparison of financial risks from the NSDP project and the literature

Financial risks	NSDP*	Selected references									
		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	No.
Bankruptcy of consortium member/s	x		x								1
Unfavourable (poor) economy in the host country	x		x			x					2
Tariff adjustment uncertainty of the water product	x			x		x	x	x	x		5
Rate of return restrictions	x		x						x		2
Availability problems of the private capital	x	x	x	x	x	x		x	x	x	8
Inflation rate volatility	x	x	x		x	x	x	x			6
Lack of guarantees	x		x								1
High construction costs	x	x	x		x			x		x	5
Insufficient performance during operation	x		x		x	x					3
Lack of creditworthiness	x		x				x		x		3
Fluctuating demand	x				x	x	x	x			4
Prolonged approval time for the project	x		x		x					x	3
Taxation risk	x	x	x				x				2
Poor contract design	x					x					1
Operation cost overruns	x		x		x	x	x	x			5
Errors in forecasting the demand	x		x			x					2
Foreign exchange rate volatility	x	x	x	x		x	x	x		x	7
Unfavourable (poor) economy of the country of the main stakeholders	x		x								1

*NSDP = Nungua Seawater Desalination Plant project
[1] = Lam and Chow (1999); [2] = Xenidis and Angelides (2005); [3] = Wang et al. (2000); [4] = Li and Zou (2011); [5] = Ameyaw and Chan (2015a); [6] = Zeng et al. (2007); [7] = Wibowo and Mohamed (2010); [8] = Choi et al. (2010); [9] = Lee and Schaufelberger (2014)

Risks not applicable to the NSDP project:
1. unpaid bills by customers; 2. supporting utilities risk; 3. design deficiency; 4. land unavailability; 5. water theft by consumers; 6. high bidding costs; and 7. technology risk

Table 4. Designation of members of the risk assessment team

ID	Participant position	Participant organisation	Years of water industry experience	Familiarity to NSDP project	Participant role
A	Manager, Business Planning	Ghana Water Company Ltd (GWCL)	7	Very familiar	Member of the concession contract preparation team. Involved in project negotiations.
B	Director, Project Development and Investment	PPP Advisory Unit – Public Investment Division	25	Very familiar	Involved in all contract negotiations with project developer/investors for the government, including risk allocation.
C	Manager, Water Sector	Public Utilities Regulatory Commission (PURC)	30	Very familiar	Involved in the tariff review and negotiations with the private consortium.
D	Project Manager	Hydrocol Ghana*	13	Very familiar	Involved in all stages of the project, risk-related negotiations with the GWCL, PURC and sponsors.
E	Project Coordinator	Hydrocol Ghana	4	Very familiar	Project management team member for the local private partner. Involved in project negotiations, such as tariff negotiations.
F	Project and Financial Analyst	PPP Advisory Unit – Public Investment Division	35	Very familiar	In charge of project control and financial feasibility for the government. Involved in preparing the contract agreement.
G	Manager, Projects Construction and Contracts Management	Ghana Water Company Ltd (GWCL)	27	Very familiar	In charge of the project for GWCL. Involved in preparing the concession contract, negotiations and finalizing the concession agreement. Member of the project management team.

*Local partner to the NSDP project

Table 5. Linguistic variables for quantifying risk criticality and project risk

Risk criticality	Project risk level	Numerical range
Not critical	Not risky	< 1.51
Very low criticality	Very low risk	1.51 – 2.50
Low criticality	Low risk	2.51 – 3.50
Moderately critical	Moderately risky	3.51 – 4.50
Critical	Risky	4.51 – 5.50
Very critical	Very risky	5.51 – 6.50
Extremely critical	Extremely risky	> 6.50

Table 6. Evaluation results of the financial risks

ID	Critical financial risks	Criticality index	Standard deviation	Weighting function	Rank**	Criticality level*
r_1	Bankruptcy of consortium member/s	6.00	0.89	0.061	1	Very critical
r_2	Unfavourable (poor) economy in the host country	5.71	0.95	0.059	2	Very critical
r_3	Tariff adjustment uncertainty of the water product	5.71	1.38	0.059	3	Very critical
r_4	Rate of return restrictions	5.57	0.53	0.057	4	Very critical
r_5	Availability problems of the private capital	5.57	0.79	0.057	5	Very critical
r_6	Inflation rate volatility	5.57	1.27	0.057	6	Very critical
r_7	Lack of guarantees	5.50	0.84	0.056	7	Very critical
r_8	High construction costs	5.50	1.22	0.056	8	Very critical
r_9	Insufficient performance during operation	5.43	0.79	0.056	9	Critical
r_{10}	Lack of creditworthiness	5.43	0.79	0.056	9	Critical
r_{11}	Fluctuating demand	5.40	1.64	0.055	11	Critical
r_{12}	Prolonged approval time for the project	5.29	1.38	0.054	12	Critical
r_{13}	Taxation risk	5.17	1.60	0.053	13	Critical
r_{14}	Poor contract design	5.14	0.69	0.053	14	Critical
r_{15}	Operation cost overruns	5.14	1.21	0.053	17	Critical
r_{16}	Errors in forecasting the demand	5.14	0.69	0.053	14	Critical
r_{17}	Foreign exchange rate volatility	5.14	1.21	0.053	17	Critical
r_{18}	Unfavourable (poor) economy of the country of the main stakeholders	5.14	1.07	0.053	16	Critical

*Refer to Table 4 for definition of terms and their ranges.
**Where two or more factors scored the same mean, the highest ranking is assigned to the one with the least standard deviation.

Table 7. Checking reliability of the risk assessment result

Overall project financial risk index = 5.43 (Risky [R])			
ID	Critical financial risks	Project risk level (score) if risk item deleted	Linguistic project risk level
r_1	Bankruptcy of consortium member/s	5.06	Risky (R)
r_2	Unfavourable (poor) economy in the host country	5.10	Risky (R)
r_3	Tariff adjustment uncertainty of the water product	5.10	Risky (R)
r_4	Rate of return restrictions	5.11	Risky (R)
r_5	Availability problems of the private capital	5.11	Risky (R)
r_6	Inflation rate volatility	5.11	Risky (R)
r_7	Lack of guarantees	5.12	Risky (R)
r_8	High construction costs	5.12	Risky (R)
r_9	Insufficient performance during operation	5.13	Risky (R)
r_{10}	Lack of creditworthiness	5.13	Risky (R)
r_{11}	Fluctuating demand	5.13	Risky (R)
r_{12}	Prolonged approval time for the project	5.14	Risky (R)
r_{13}	Taxation risk	5.16	Risky (R)
r_{14}	Poor contract design	5.16	Risky (R)
r_{15}	Operation cost overruns	5.16	Risky (R)
r_{16}	Errors in forecasting the demand	5.16	Risky (R)
r_{17}	Foreign exchange rate volatility	5.16	Risky (R)
r_{18}	Unfavourable (poor) economy of the country of the main stakeholders	5.16	Risky (R)