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Original citation & hyperlink:

Ameyaw, EE, Chan PC, A, Owusu-Manu, D-G, David, EJ & Dartey, F 2017, 'A fuzzy-based evaluation of financial risks in build-own-operate-transfer water supply projects' *Journal of Infrastructure Systems*, vol 23, no. 4, 04017033.
https://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000390

DOI 10.1061/(ASCE)IS.1943-555X.0000390
ISSN 1076-0342
ESSN 1943-555X
Publisher: American Society Of Civil Engineers

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 to develop new infrastructure assets. The BOOT scheme is particularly suitable for the delivery of bulk

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water supply (Lianyu and Tiong, 2005). From 1990 to 2011, 58% (439 projects) of 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, 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. 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 this 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 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 the 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.

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, 2015b; 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 in water-based PPP projects. 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).

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 technique 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 (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 that are of 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 4) 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

Previous studies that had a focus on identification of financial risks 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 a checklist 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 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 2 reports upon the risks identified from the related literature.

[Insert Table 2]

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 asked to indicate the important financial risk factors that apply to the NSDP project. 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. Of the 25 risk factors 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 2 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 formulated into a questionnaire for a survey.

Questionnaire survey

Project background – Nungua Seawater Desalination Plant (NSDP)

A questionnaire survey was conducted on the NSDP to measure how the project participants perceive the relative significance of the identified risks associated BOOT water supply projects in Table 2. 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 Limited (also known as Befesa–Ghana which is 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 3 summarizes the participants' 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 limitations. 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 participants 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 4). 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 measure criticality levels of the risks and overall risk index of the 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 mean criticality scores were calculated using Equation (4) below. Standard deviation values were calculated using SPSS 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 Using 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 the 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 (MF_{r_i}) 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:

$$MF_{r_i} = \frac{a_{i1}}{v_1} + \frac{a_{i2}}{v_2} + \ldots + \frac{a_{in}}{v_n} = \frac{a_{i1}}{\textit{not critical}} + \frac{a_{i2}}{\textit{very low criticality}} + \ldots + \frac{a_{in}}{\textit{extremely critical}} \qquad (1)$$

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:

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

For example, regarding *unfavourable economy in the host country* ($\mathbf{r}_2$), the expert evaluation results suggested that the risk assessment team scored its impact on the NSDP as follows: 0% as ‘not critical’; 0% as ‘very low criticality’; 0% as ‘low criticality’; 14.3% as ‘moderately critical’; 14.3% as ‘critical’; 57.1% as ‘very critical’; and 14.3% as ‘extremely critical’. Using Eq. (1), the membership function (MF) is derived as:

$$MF_{r_2} = \frac{0.000}{\text{not critical}} + \frac{0.000}{\text{very low criticality}} + \frac{0.000}{\text{low criticality}} + \frac{0.143}{\text{moderate}} + \frac{0.143}{\text{critical}} + \frac{0.571}{\text{very critical}} + \frac{0.143}{\text{extremely critical}}$$

and the single-factor evaluation vector is written through Equation (2) as:

(0.000, 0.000, 0.000, 0.143, 0.143, 0.571, 0.143)

Consequently, the single-factor evaluation vectors of all the 18 risks are expressed in a fuzzy relational matrix as follows (to 2 d.p.):

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

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 risk assessment team using linguistic values (which can be considered an ordinal measurement system) and is representative of the risk assessments of the respondents.

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

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.

Using Equation (4) the criticality score of risk of *unfavourable economy in the host country* (**$\boldsymbol{r}_2$**)

is derived as:

$$Z_2 = (0.00\times 1 + 0.00\times 2 + 0.00\times 3 + 0.143\times 4 + 0.143\times 5 + 0.157\times 6 + 0.143\times 7) = 5.714$$

The third column of Table 5 shows the computation of Z_1 to Z_{18}. Arranging the Z_i values in decreasing order of magnitude can determine the criticality 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 factor prioritization 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 (Yeung et al., 2007) to obtain weightings of the risk factors. 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):

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

Therefore, the normalized weighting function set is

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

Using equation (5) weighting functions of the risk factors are obtained and presented in fifth column of Table 5. 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:

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

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

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

$$D = \frac{0.00}{\text{not critical}} + \frac{0.00}{\text{very low criticality}} + \frac{0.01}{\text{low criticality}} + \frac{0.19}{\text{moderate}} + \frac{0.36}{\text{critical}} + \frac{0.25}{\text{very critical}} + \frac{0.19}{\text{extremely critical}} \tag{11}$$

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

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).

$$Z_{\mathrm{FRL}} = \sum_{k=1}^{\circ} d_k \cdot k = 0.00 \times 1 + 0.00 \times 2 + 0.01 \times 3 + 0.19 \times 4 + 0.36 \times 5 + 0.25 \times 6 + 0.19 \times 7 = 5.4312 \tag{12}$$

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 6 provides 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 6 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 6]

Discussion of Results from the FSE Analysis

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) (Tables 5 and 6). The project stakeholders should develop and implement effective mitigation measures to neutralize the adverse consequences of the risks. Second, all the risk factors are risky because their mean criticality ratings range between 5.14 ('critical') and 6.00 ('very critical') categories. Table 5 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 risk factors 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.

Bankruptcy of consortium member(s)

The risk factor is assessed as the top-ranked risk with a 'very critical' rating (Table 5). It informs the government that smooth progress and completion of the NSDP project can be jeopardized in case the concessionaire files for bankruptcy. This is critical because a potential bankruptcy risk may or may not necessarily relate to the NSDP project but to other business operations of the consortium members (Xenidis and Angelides, 2005). For example, in the Tampa Bay Seawater Desalination Plant project, Because of the poor and mistrustful relationship between Covanta Tampa Construction (awarded a construction contract and 30-year concession to operate and maintain the facility) and Tampa Bay Water, the former filed for bankruptcy in October 2003; other 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). Thus, bankruptcy risk will adversely affect NSDP project in terms of cost and time, given that Ghana Water Company will have to replace the concessionaire, Befesa-Ghana.

Unfavorable economy of the host country

The risk reminds the government, Ghana Water Company and Befesa-Ghana that the Ghanaian economic environment has a significant influence on the eventual success of the NSDP project (Xenidis and Angelides, 2005). The result indicates that the risk assessment team is highly concerned with the unstable local economy with structural deficiencies, immature and undersized stock market, foreign exchange fluctuations, currency devaluation, corruption, and fluctuation in interest and inflation rates (Ameyaw and Chan, 2015a). The implication of poor economy is that the Ghana government may fail to meet agreed guarantees, honor its payment obligations under the contract, or cost slippage problems may occur, which will have a negative impact on smooth implementation of the NSDP project. The significance of poor economy on BOOT projects is supported by past research; 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).

Uncertainty in the tariff adjustment of water products

This risk hints that the risk assessment team is concerned with the commitment of the current or future government to accept upward adjustments of the operating tariff in case of unexpected macroeconomic conditions (such as high inflation rate, currency devaluation, foreign exchange volatility, etc.) during the 25-year concession period. Such unfavorable local conditions are frequently beyond the control of the concessionaire (Befesa-Ghana in this case) and may require a revision/adjustment of the operating tariff. The risk also reflects Ghanaian governments' history of opposing water tariff increases and their implementation in a timely manner (Ameyaw and Chan, 2015a). The risk is likely to affect the confidence of the concessionaire. Over the past decade, two BOOT water projects were initiated and eventually abandoned following a lack of assessment of public concern over water tariffs and foreign (private) company involvement in public water services, which resulted in public resistance and protests. Elsewhere, tariff adjustment in BOOT contracts in China is the most critical risk issue 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). In addition, the 'very critical' rating of the risk in this study 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 supply projects in developing countries. Potential implications of uncertainty in tariff adjust on the NSDP will include low operating margins and poor service levels and unpredictable revenue flow and profit levels, which will threaten long-term sustainability of the Befesa-Ghana and the project itself.

Rate of return restriction risk (profitability)

Ranked forth, this risk 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 NSDP project, for example, 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 risk assessment team is concerned that a future government may retain a rate of return for the investment. Experience suggests 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 rate of return of the NSDP project will generate serious consequences, as reflected by its 'very critical' score. These consequences include a reduction in the viability of the NSDP, because the cap will limit the ability of the Befesa-Ghana and its investors to balance the project's risks with corresponding return (Wang et al., 2000), and also discourage potential investors from participating in similar infrastructure projects in the country in future.

Availability problems of private sector capital

The risk of availability of private capital reminds both the Ghana government and private water developers of the difficulties in raising sufficient finances on time for water supply infrastructure projects in a developing country like Ghana. This difficulty reflects reluctance of financial institutions and private water developers to provide sizeable funds because of the perceived high-risk profile of the country and its water sector (Ameyaw and Chan, 2015a). With a 'very critical' score (5.71), the risk assessment team is concerned with funding unavailability until the completion of the desalination plant construction. This is important because it relates to a successful implementation of the project; when the NSDP project was first awarded to a Norwegian developer (Aqualyng) in 2008, the developer failed to raise financing 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). This finding supports the results of previous studies (Li and Zou, 2011; Wang et al., 2000; Tiong, 1990) which showed that a major aspect of the successful execution of the BOOT model is raising financing. Responding to financing risk requires innovative approaches to the financing and security of private investments through provision of guarantees by the Ghana government (e.g., foreign exchange guarantees, interest subsidies, revenue guarantees, tariff guarantees, off-take agreements, 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

This research identified and assessed the financial risks in a BOOT water supply project using the FSE technique. The risk assessment results of the NSDP project showed the project can be regarded as financially risky, and that the FSE technique can be used to evaluate and prioritize risk factors in terms of their criticality and to rank BOOT projects regarding their overall risk levels. The risk assessment results suggest that for a top five risk factors in a typical BOOT water supply project in the Ghanaian environment are bankruptcy of consortium member(s), unfavourable economy of the local economy, uncertainty in the tariff adjustment of water products, restrictions on the rate of return, and availability problems of the private-sector capital.

These risk factors must be the initial focus of the government and private water developers/investors if they are to effectively manage the risks associated with BOOT water projects. Four out of the top-five risk factors discussed (unfavourable economy of the local economy, uncertainty in the tariff adjustment of water products, restrictions on the rate of return, and availability problems of the private-sector capital) relate to the Ghana's economic environment and/or government actions. A country's economic environment and government actions poses significant risks to the infrastructure sector, because such risks influence financial structures supporting sustainability of infrastructure projects. Going forward with its PPP programme, the Ghana government needs to develop innovative ways to address these important risk issues.

To extend and validate the wider applicability of the FSE technique and the shortlisted risk factors, more research is required, for example, to test the applicability of the risks across infrastructure sectors where BOOT/PPP is applied or increasingly considered by the government, such as energy/power, transport, social sector (education and prisons).

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Tables

Table 1. 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 2. 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 3. 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 4. 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 5. 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 6. 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)

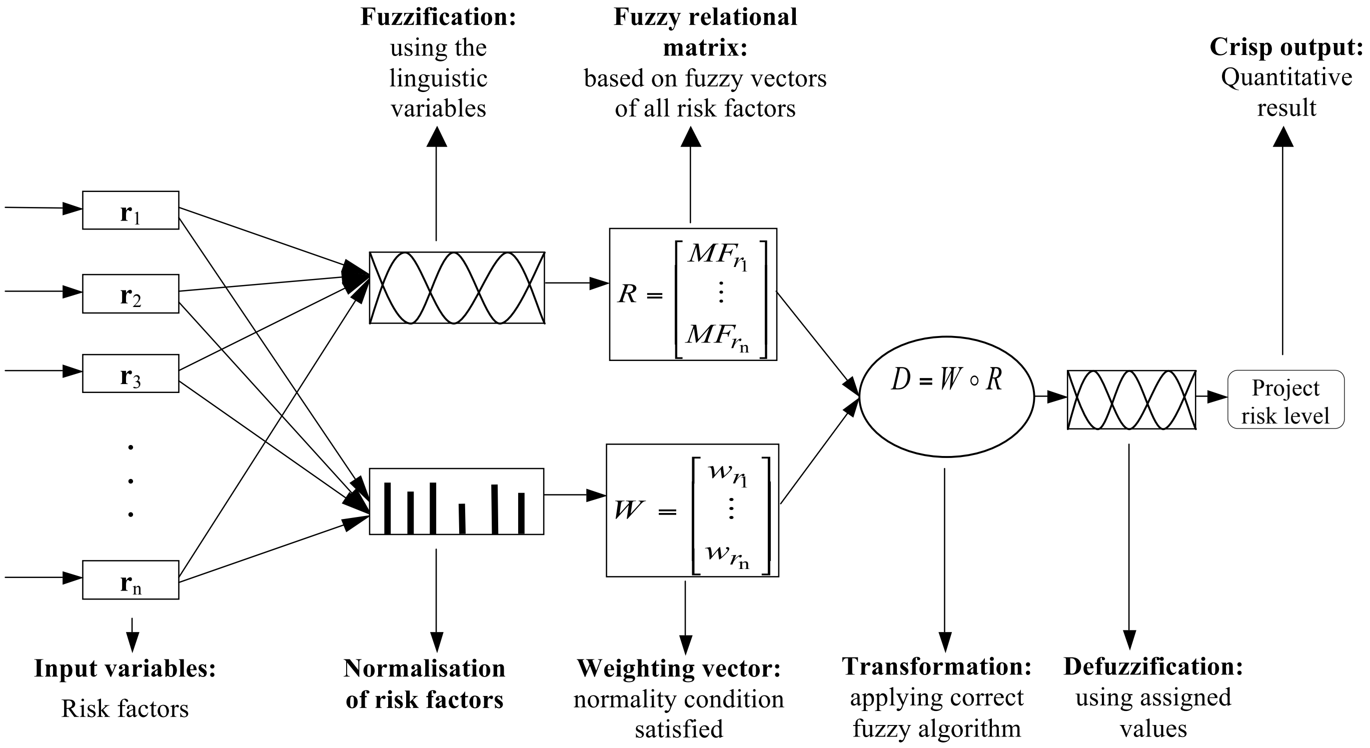

Fig. 1 FSE-based risk assessment process

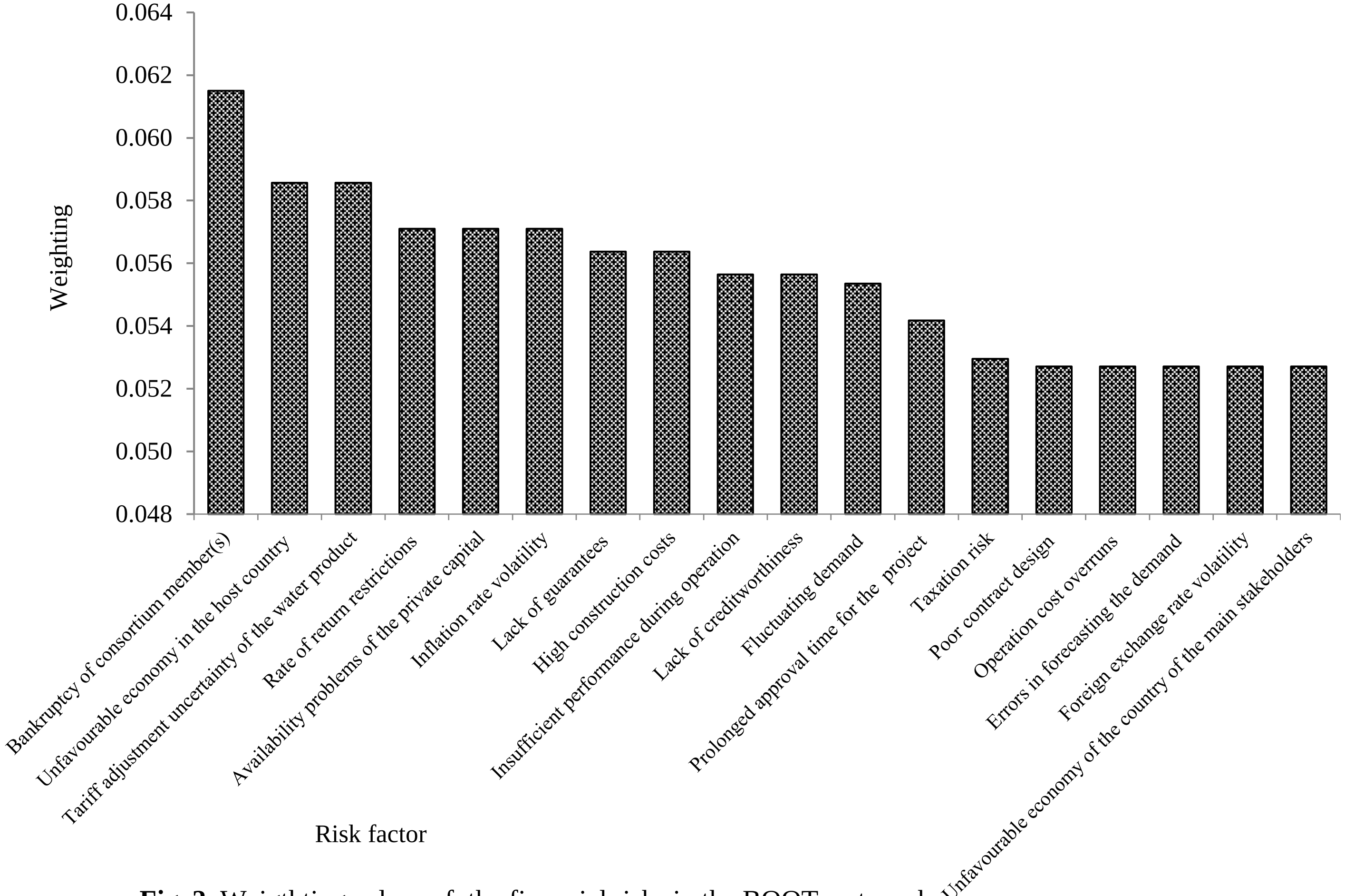

Fig. 2. Weigthting values of the financial risks in the BOOT water scheme

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The authors wish to thank the referees for their constructive comments and suggestions which aimed at improving the paper. Each individual comment has either been addressed or defended as appropriate (refer below) and a final file resubmitted for your consideration. Once again, thank you.

Reviewers' Comments	**Authors' response**
All reviewers	
This manuscript was submitted as a Technical Paper. Does the reviewer think this is the appropriate article type? To see descriptions of the article types, Click Here.	The authors are delightful to read this feedback – thank you.
Reviewer #1: Yes. The author is using the correct article type. Reviewer #2: Yes. The author is using the correct article type. Reviewer #3: Yes. The author is using the correct article type.	
Reviewer #1: General comments	
After a careful reading of the manuscript I really like the study and I feel it can have a lot of impact in the field. However, I suggest to accept the manuscript after some Moderate or Minor Revisions. Below I provide some recommendations of topics that you may want to include in the revision: I think these topics can be explored further down the line in additional projects / papers but needs to have some clarification here in this paper at least.	The authors than the reviewer for the comment.
The first comment is about the choice of the fuzzy logic model that has been largely criticized in the literature versus other decision-structured analytical models that consider uncertainty. Also, uncertainty can and must be characterized using the probability distribution functions inferred from data or hypothesized rather than using fuzzification. Yet, I think that some caution should be placed in the model.	The fuzzy set technique is able to handle uncertainty and subjectivity (see Boussabaine and Elhag, 1999; Lo, 1999; Hsiao, 1998). The methodology adopted in this paper handles the decision makers' uncertainty and subjectivity of evaluation, as outlined in a full paragraph 3, page 6: Line 183–203: *"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) … "*

	Also, the fuzzy-based approach objectifies decision makers' subjective evaluations by a predetermined fuzzy composite function (see Lo, 1999; Hsiao, 1998). The weighted mean method (Eq. [9]) is used in our analysis to quantify the fuzzy membership grades level by level from sub-criteria to the upper-criteria. This is a hierarchical process which further improves reliability of evaluation results. From the above, and the risk management literature (e.g., Boussabaine, 2014; Khatri et al., 2011; Tah and Carr, 2000), the fuzzy set theory has been successfully used to handle uncertainty and imprecision of evaluation. We agree to the reviewer's suggestion that uncertainty should be characterized through probability distribution functions inferred from data. And so, we are characterizing uncertainty in this way in our next research papers – we are thankful for this.
Second, I suggest to mention at least the existence of portfolio decision models (such as the one in Convertino and Valverde, 2013) that are better than MCDA as well and include global sensitivity and uncertainty analyses.	Thank you for your suggestion here. We have mentioned these methods (portfolio decision, global sensitivity analysis and uncertainty analysis) in the 'Limitation and further work' section of the paper, which we will be applying in subsequent papers/research projects; Lines 658–663: *"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) …"* Space limitations (imposed by the Journal) will not permit us to include these methods in the current paper. The revised manuscript exceeds slightly the suggested word limit.
Lastly my two minor observations are about the lack of global sensitivity and uncertainty analyses (GSUA) and a conversation about management implications that we can extract from the model/GSUA.	We thank the reviewer for the comment. First, as indicated earlier, we are applying GSUA to risk management in our further research. Space limitation does not allow us to include the suggested methods in this manuscript. We have acknowledged this in in the paper. In addition, the design (including sample size) of the current study does not make it easy to apply the suggested methods in the current paper. We will use a big sample size in order obtain good results from these methods.

Particularly, GSUA is very important because it given an idea of what is driving the output in term of model input factor importance and interaction, and how that can be used for management. In your case I do not expect different results of GSUA for different models but GSUA can highlight factor importance and interaction for predicting PM2.5.	Second, we have discussed the management implications of the study under *Discussion of Results from the FSE Analysis*, with a focus on the 'very critical' risk factors regarding how they affect the BOOT project (Lines 522–624) and then the implications of the fuzzy methodology for practitioners (Lines 626–635). As stated, we have not used GSUA in the current paper. We are interested in GSUA and we explored it in the further work of this research.
GSUA is a variance-based method for analyzing data and models given an objective function. It is a bit unclear how many realizations of the model have been run and how the authors maximized prediction accuracy. Are the values of the input factors taken to maximize predictions? GSUA (see references below) typically assigns probability distribution functions to all model factors and propagate that into model outputs. That is useful for assessing input factor importance and interaction, regimes, and scaling laws between model input factors and outcomes. This differs from traditional sensitivity analysis methods (that are even missing here)	The fuzzy methodology used in our analysis converts linguistic variables (input) into quantitative outcomes, allowing the decision maker to obtain the risk level of the project (as in this case). It is not based on objective functions. As illustrated under 'Results obtained from FSE analysis' and operationalised in Fig. 1, the fuzzy methodology contains series of steps that transforms input data into a crisp output. This is a good comment, we thank the reviewer. However, from the literature on fuzzy set approach, the technique is applied to qualitative data without running sensitivity analyses. And this does not affect the reliability of the outputs. The FSE has been used as a stand-alone method or with other techniques to resolve many practical problems; some of these studies are provided in Table 1. As indicated earlier, suggestions regarding applying GSUA is well taken and will be implemented in subsequent papers.
I also suggest to include figures rather than tables to communicate results. They are much more effective. Thanks.	We agree with tour comment and have included a figure to communicate the results; Fig. 2 presents the weightings of the risk factors.
Specific comments about GSUA	
Variance-based methods (see Saltelli and Convertino below) are a class of probabilistic approaches which quantify the input and output uncertainties as probability distributions, and decompose the output variance into parts attributable to input variables and combinations of variables. The sensitivity of the output to an input variable is therefore measured by the amount of variance in the output caused by that input. Variance-based methods allow full exploration of the input space, accounting for interactions, and nonlinear responses. For these reasons	We appreciate the comments and suggestions and references provided by the reviewer – thank you. We are exploring these methods in risk management of PPP projects in our next papers for which we will be using big sample sizes to ensure good results from these variance-based methods. This paper is based on a single case study, with participation from a risk assessment team of seven project participants. Having looked at these methods, they will provide interesting results when applied to PPP projects.

they are widely used when it is feasible to calculate them. Typically this calculation involves the use of Monte Carlo methods, but since this can involve many thousands of model runs, other methods (such as emulators) can be used to reduce computational expense when necessary. Note that full variance decompositions are only meaningful when the input factors are independent from one another. If that is not the case information theory based GSUA is necessary (see Ludtke et al.) Thus, I really would like to see GSUA done because it (i) informs about the dynamics of the processes investigated and (ii) is very important for management purposes. However, in this context I feel like the models are already extremely comparable and GSUA would not give additional information except for the information of variable relative importance and interaction. Convertino M, Valverde LJ Jr (2013) Portfolio Decision Analysis Framework for Value-Focused Ecosystem Management. PLoS ONE 8(6): e65056. doi:10.1371/journal.pone.0065056 Convertino et al. Untangling drivers of species distributions: Global sensitivity and uncertainty analyses of MaxEnt. Journal Environmental Modelling & Software archive Volume 51, January, 2014, Pages 296-309 Saltelli A, Marco Ratto, Terry Andres, Francesca Campolongo, Jessica Cariboni, Debora Gatelli, Michaela Saisana, Stefano Tarantola Global Sensitivity Analysis: The Primer, ISBN: 978-0-470-05997-5 Ludtke et al. (2007), Information-theoretic Sensitivity Analysis: a general method for credit assignment in complex networks J. Royal Soc. Interface	We have expressed interest in applying these methods in next projects in Limitation and further work section (Lines 658–663).
Reviewer #2	
Overall the paper presents a very good methodology on handling subjective uncertainties on Build-own-operate-transfer (BOOT) scheme applied to bulk water supply projects. The paper has some scholarly contribution with the fuzzy sets mathematics well-explained and the results well-narrated.	We are delighted to read this positive feedback and the suggestions (below) – thank you.
There may be a need to explain why the fuzzy sets-based method would be better than an equivalent probabilistic model where, say, data is available to model these criteria with the uncertainties.	Thank you for your constructive suggestion. We have provided three major reasons from using the fuzzy set approach in this paper: Lines 175-181: *“A major advantage of FSE is that the analysis does not always require statistically significant sample size … ”*

Some of the literature references (format) may also need to be reviewed.	These reasons are summarised as follows: 1. Fuzzy set does not always require a significant sample size (Li et al., 2000) 2. Data is required for only the lower-level attributes (Hsiao, 1998) 3. The fuzzy set approach takes into account concepts such as uncertainty and vagueness in data (Jato-Espino et al., 2014; Boussabaine and Elhag, 1999). We agree with your observation here and have reviewed the references as appropriate.
Reviewer #3	
The objective of the paper was to investigate the financial risks associated with BOOT in water projects. The authors have developed a set of questionnaires to identify the financial risk indicators, classified the indicators values using expert opinions, applied the fuzzy set and fuzzy synthetic approaches to synthesize the selected indicators into the index and calculate the financial risk of Nugua Seawater Desalination Plant in Ghana. The paper is average in merit; interesting to read; unsure this could be bet fit to the ASCE's Journal of Construction Engineering and Management.	We are delighted to read this positive feedback – thank you. Regarding suitability of our paper in J. of Infrastructure Systems, we believe it is a best fit for this journal as it accepts and publishes papers on PPPs for infrastructure development, such as: Zhang, X. Q., and Kumaraswamy, M. M. (2001). "BOT-based approaches to infrastructure development in China." *J. Infrastruct. Syst.*, 10.1061/(ASCE)1076-0342(2001)7:1(18), 18–25. Ke, Y., Wang, S., and Chan, A. P. C. (2010a). "Risk allocation in public-private partnership infrastructure projects: Comparative study." *J. Infrastruct. Syst.*, 10.1061/(ASCE)IS.1943-555X.0000030, 343–351. Chan, A., Lam, P., Wen, Y., Ameyaw, E., Wang, S., and Ke, Y. (2014). "Cross-Sectional Analysis of Critical Risk Factors for PPP Water Projects in China." *J. Infrastruct. Syst.*, 10.1061/(ASCE)IS.1943-555X.0000214, 04014031. Also, the Editor, Professor Sue McNeil, has indicates that PPPs is one of the 'hot' topics (http://ascelibrary.org/page/jitse4/editorjis). Hence, this work which focuses on BOOT for water projects is a well fit for the journal.
The introduction and literature review sections of the paper is clear; however, it has very weak methodology, results and discussion sections. The latter part of the paper is not concise, and to some extent beyond their own work and findings. In my view, the paper needs additional work to make it publishable,	We thank the reviewer for the constructive comments. We address these comments as follows.

and the authors are requested to address the following comments if they would like to resubmit for a journal publication.	
Major comments:	
1)Authors presented that "there is a limited number of research studies on, and hence a less understanding of, financial risks affecting water projects, especially, in developing countries (lines:75-76)". Also, "BOOT water supply projects face financial risks not only because of their complexity" (line:90). However, there is no explanation on what those parameters are of water sectors in developing countries that makes it different from developed countries;	To the best of our knowledge there are no definitive studies comparing differences in water PPPs in developing and developed countries. Hence, we do not intend to provide comparisons, but submit that: Lines 78–82: *Developing countries are associated with higher risks resulting from unfavourable 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.*
why risk assessment methods developed/applied in other sectors such as road and power cannot be applied to water sectors;	Lines 87–89: We have not covered risk assessment methods and their applicability to different infrastructure sectors. Such a comparison is beyond the purpose of this paper. However, we made reference to Cheung and Chan's (2011) which found differences in critical risks faced by water, transportation and power projects, to highlight a need for sector-specific risk assessments.
what are those special attributes of water sectors that makes it complex and challenging from the financial perspectives?	We have amended this part by providing a summary of characteristics of the water sector that make it difficult from financial perspectives: Lines 91–101: *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, 2015b; see Ameyaw and Chan (2013) for discussion):*

I don't think Table:1 presents a convincing and sufficient evidence to the study.	- *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);* - *…* We thank the reviewer for this comment. We agree with the reviewer and Table 1 is removed from the revised version.
2) A set of 18-risk indicators were selected after the literature review and consultation with the experts (Table 6). I am unsure how many of those indicators are meaningful, how they can measure the different aspects of the financial risks, and which of those are water sectors and developing countries related. What if-if they consider only 7-8 indicators? Would the results be changed by doing so?	We thank the reviewer for the comment. The risk factors used for the study are meaningful in that they were initially selected after a review of literature and project documentation - this is expected of a study of this nature. Following this, the risks were further scrutinized through expert consultation in order to determine those risks relevant/applicable to the case project (Table 2). The above steps generated 18 (out 25) risks that are useful to the study. Again, the literature sources of the risks are provided in Table 2; these risks are consistent with those reported as financial risk category in the PPP literature (summarised in Lines 145-152; and detailed in Lines 220-288 and 310-359). Following the above, the 18 risks were assessed by a team of practitioners who have a direct involvement in the case project. Of course, each risk will have a different level of impact on the project, and where a different number (say 7–8 as suggested) of risk variables are used, the extent of their impact (overall risk level) will differ; this is because, by our methodology, the effect/contribution of each risk is accounted for in the overall index. So, the overall index which measures the risk level is dependent of the contributions of all risks.
3) Despite their reasons for choosing the fuzzy set theory in their application, the manuscript does not present the important procedures of the fuzzy synthetic evaluation. I cannot see anywhere how the indicators were characterized - meaning what are the fuzzy values (to class into fuzzy membership functions), and what is the basis of classifying them into a "risky" or "not risky" group? The paper must present membership functions of all the risk criteria and basis of their classification.	We thank the reviewer for the comment. As noted by the reviewer, the fuzzy synthetic evaluation (FSE) approach is applied in the analysis. FSE works without building traditional triangular or trapezoidal fuzzy membership functions and the approach adopted is consistent with what is reported in the literature (see for example Li et al., 2013; Chan, 2007; Hsiao, 1998; Ameyaw and Chan, 2015b). In FSE analysis, and in this paper, membership functions can be, or are, derived directly from the expert evaluation using appropriate fuzzy equations (Chan, 2007;

	Li et al., 2013). We showed how the membership functions were derived through Eqns. (1) and (2). In comparison with other fuzzy-based methods, this is one of the features of FSE that makes it widely applicable. We used a seven-point grading scale to solicit the value judgment of the risk assessment team regarding the criticality of the risks. Based on the seven-point scale, a factor prioritization scale was developed for the risk factors and the overall risk index of the case project (NSDP), as in Table 4. This factor prioritization approach is appropriate and has been used in previous studies (see e.g., Murphy et al., 2015; Li et al., 2013). Following the above, and regarding the classification of the NSDP project as 'risky', we submit in *Step 5: Defuzzify the fuzzy vector of the project risk level* as follows: Lines 493-496: *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).* The scale helps to generate rankings of the risks and their membership function sets, in order to quantify the criticality levels of the risks and subsequently the overall risk index of the case project (NSDP).
4) Figure 1 is not clear and correct. Please correct that with the right steps: such as fuzzification (membership development), normalization, assignment of weights and further.	We thank the reviewer for the comment. Per the application of the FSE technique, Fig. 1 is correct and captures all the necessary steps which are summarised as follows (Li et al., 2013; Hsiao, 1998): 1. Establish a set of basic criteria (or factors) 2. Establish a set of grade alternatives (expressed in linguistic terms) for the factors 3. Establish a set of weightings by computing the weight vectors of the evaluation factors s: 4. Determine a fuzzy evaluation matrix $R = (r_{ij})_{mxn}$

	5. Determine the final fuzzy evaluation by considering the weightings (Step 3) and fuzzy evaluation matrix (step 4) through the appropriate fuzzy equation. Figure 1 reflects the steps involved in applying the FSE and it is consistent with how FSE is applied and reported in the literature – fuzzification, normalisation, fuzzy relational matrix, weighting vector, transformation (application of one of the five fuzzy operators), and defuzzification (see Lo, 1999; Hsiao, 1998; Chan, 2007). The steps outlined in Fig. 1 are also explained/illustrated in Step 1 through Step 5 in the manuscript (Lines 384-502). In these steps, we showed how the relevant equations are derived and applied through the survey data obtained from the risk assessment team.
5) The paper must illustrate each step of the method with an illustrative example (after line 375). For example, if you are presenting the fuzzificaiton process, you should illustrate with an example.	We thank the reviewer for the comment. Overall, we present the fuzzy approach with illustrations from the survey results. Where appropriate, we indicate how a particular result was derived. In the revised manuscript, we show how the membership functions of the risks were obtained using Equations 1 and 2 (Lines 402-406). Also, we show how the criticality scores were calculated using Equation (4) in Lines 407-416. As a result of space limitation, where the equation is self-explanatory/straightforward, the result is presented, such as in determining the weighting functions and the normalised weighting function set through equations (5) and (6). We believe the read is able to follow the steps outlined in this manuscript.
6) The paper does not present results clearly - it's too vague. Please present what are the main findings? What are the sensitivity of the results? What are the key sector specific and region specific indicators to be considered for the risk assessment? Present your tabulated results.	We thank the reviewer for this comment. The entire manuscript is structured under the following major headings (with sub-headings): 1. Introduction and research background 2. Research methods 3. Evaluation of survey results using FSE analysis 4. Discussion of results from FSE analysis 5. Limitation and further work 6. Conclusion

	In section 2, we present relevant information about data collection regarding the 18 risk factors that were used in the risk assessment survey. Note that these shortlisted risk factors are the primary factors relevant in this study and subjected to a risk assessment by a team of practitioners involved in the case project. And then in section 3, the FSE is applied to perform the risk analysis based on outcome of section 2. The mean criticality and ranking of the 18 risks as well as the risk level of the project were determined. Here, all relevant results are tabulated and/or presented in figure. Following the above, a discussion based on risk level of the project and the top five risks were discussed in section 4. Note that the discussion of top-five risk factors is due in part to space limitation, as all the 18 risk factors are very critical or critical. The headings and subheadings are structured to reflect the focus of each section to ensure order and to avoid vagueness.
7) The readers will not be interested to read the discussion section that was derived from others work (line: 494 to 598). In my view, the discussion section is redundant (although some of the information synthesized will have potential added values BUT not in this place), one should present what was found from their study and would have compared/contrasted to others results. Please present your results and discuss based on your analysis, case, and results. Similar redundancy can be observed in the conclusion section. I hope the conclusion will be redrawn along with the revision of the results.	We thank the reviewer for this constructive comment and the suggested approach to the discussion of the results. As suggested, we present the outcome of the FSE analysis and then discuss based on the overall risk level and top-five risk factors of the case project. We have made the NSDP the focus of the discussion (although with reference to other examples). We also made an effort to and compare/contrast the results with other cases or published literature, which is useful given that our analysis draws on a single case and to enrich our understanding of the critical risk factors. Reference to the literature further supports why the risks identified in the current study are critical. However, an effort was made to remove redundant information from the discussion. The Conclusion is re-drawn to reflect the preceding results and discussion. The redundant information is eliminated.
Minor Comments:	We thank the reviewer for the following questions and comments.
1) What do you mean by complexity (line 90)?	This aspect has been revised to remove 'complexity' from the sentence and to better convey the intension of the authors (Lines 91-92).

2) Line: 265, how the validation was undertaken?	We submit that: Lines 274-275: *The consultant was asked to indicate the important financial risk factors that apply to the NSDP project.*
3) Line:274; what are the criteria to judge for significant?	'Significant' as used here (Line 285) denote the 18 risk factors that were considered important or applicable to the NSDP project following the review and verification of the shortlisted risk factors (25) by the consultant.
4) Lines: 346 to 349, it's unclear on how do you calculate the mean, STD...... please explain how did you do that in your case.	The mean criticality index scores were calculated through Equation (4) and this has been explained. Regarding standard deviation, we submit that: Lines 357-358: *Standard deviation values were calculated using SPSS statistical package 21.0 (Pallant, 2005).*
Associate Editor	
The reviewers provide a lot of valuable criticisms, comments, and suggestions. The author is requested to revise the paper according to the reviewers' opinions.	We are grateful to the reviewers for their constructive comments and suggestions. We have responded to all the comments appropriately.

References[1]

Lo, S.M. (1999) A fire safety assessment system for existing buildings. *Fire Technology*, 35(2), 131–52.

Li, T.H.Y., Ng, S.T. and Skitmore, M. (2013) Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: A fuzzy approach. *Automation in Construction*, 29, 123–135.

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[1] Note: Only references not included in the manuscript are provided here.