

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

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Abstract

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

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

Introduction and research background

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

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

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42 Under the BOOT scheme¹, the private developer performs new and extended responsibilities,
43 such as raising project funds, designing and constructing facilities required to deliver the bulk
44 water supply, and operating and maintaining these facilities, with a return on capital secured
45 through a long-term off-take agreement (Wall, 2013; Lianyu and Tiong, 2005; Donaghue,
46 2002). Ownership and operating rights belong to the private entity until the expiration of the
47 concession period, after which these rights are transferred to the public party. In this research,
48 BOOT includes all concession-type contracts in which finance is provided primarily by the
49 private sector to develop infrastructure assets. Variations generally adopt the primary functions
50 of the BOOT model and include build–operate–transfer (BOT), design–build–operate–transfer,
51 finance–build–own–operate–transfer, build–transfer–operate, build–lease–transfer, and
52 design–build–operate. Utility concessions are excluded from consideration in this paper².
53 However, where necessary, ‘public-private partnership (PPP)’ is also used to denote general
54 forms of private sector participation, including BOOT/its variants and utility concessions/PPPs.

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56 BOOT projects entail large private capital, a long concession period and multiple stakeholders
57 which in turn, result in an array of major risks, including political and legal risks (Ng and
58 Loosemore, 2007; Merna and Smith, 1996), social risks (Wibowo and Mohamed, 2010; Rebeiz,
59 2012), technical risks (Özdoğan and Birgönül, 2000; Zeng et al., 2007), and financial risks
60 (Xenidis and Angelides, 2005; Lam and Chow, 1999). In this study, financial risks in BOOT
61 for water supply are identified and analyzed. Financial risks occur frequently and affect water
62 infrastructure projects significantly (Ameyaw and Chan, 2015a), given the difficulty in
63 obtaining long-term financing in local currency for water projects (Matsukawa et al., 2003).
64 This creates a mismatch between currencies of financing and revenues. The mismatch, coupled
65 with depreciations of the local currency, has a damaging effect on the sustainability and
66 profitability of BOOT water supply projects (Vives et al., 2006; Lianyu and Tiong, 2005).
67 Tackling problem via pass-through provisions in the contracts has been ineffective because

68 the population is often unable to pay for the associated rate hikes. Financial risks are also
 69 associated with higher inflation rates, higher capital costs and lower operating margins or
 70 forecasted revenues, and therefore are widely linked to rising project failures (Lee and
 71 Schaufelberger, 2014; Vives et al., 2006).

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73 Although there is a a myriad of literature on the general risks in BOOT projects across
 74 infrastructure sectors (e.g., Ameyaw and Chan, 2015a; Lee and Schaufelberger, 2014; Rebeiz,
 75 2012; Wibowo and Mohamed, 2010; Ng and Loosemore, 2007; Zeng et al., 2007), there are
 76 limited studies on, and hence a less understanding of, financial risks affecting water projects
 77 especially in developing countries (Organisation for Economic Co-operation and Development,
 78 OECD, 2009). Developing countries are associated with higher risks resulting from
 79 unfavorable local conditions, such as macroeconomic factors, tariff sustainability, user
 80 willingness to pay, legal frameworks, political factors, institutional capacity and fiscal space
 81 (Vives et al., 2006; Matsukawa et al., 2003). These issues influence conditions of investment
 82 and private sector's investment decision-making. A review of literature revealed three
 83 prominent studies focused upon financial risks in BOOT projects (Xenidis and Angelides, 2005;
 84 Wang et al., 2000; Lam and Chow, 1999) but these did not consider financial risks in water
 85 BOOTs. This explains a paucity of understanding regards the risks affecting water projects
 86 (OECD, 2009) and also sheds some light on why project structures often fail to match
 87 prevailing risks (Vives et al., 2006). Moreover, Cheung and Chan (2011) showed that important
 88 risks faced by privatised water projects differ from those encountered in transportation and
 89 power projects. This suggests a need for a water sector-specific investigation of risks.

90

91 **[Insert Table 1]**
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93 BOOT water supply projects partly face financial risks to design and construct due to the
 94 sector's challenging characteristics which differentiate it from other infrastructure sectors. ,
 95 These characteristics result from the following (Ameyaw and Chan, 2015; see Ameyaw and
 96 Chan (2013) for discussion):

97

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

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

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105 These attributes could explain the difficulties encountered Failure to carefully identify,
 106 prioritize, and mitigate them often result in problems in project development and
 107 operation/maintenance (Cuttaree, 2008; Vinning et al., 2005). Several cases of
 108 distressed/disputed, terminated, or initially unsuccessful BOOT water supply projects have
 109 been reported, including the Beijing No. 10 Water Scheme, the Chengdu No. 6 Water Plant B,
 110 and the 9th Shen Yang Water Plant in China; the Thu Duc Water Plant in Vietnam; the Bogota
 111 Treatment Plant in Columbia; the Tampa Bay Desalination Plant in Florida, USA; and the Sonia
 112 Vihar Water Plant in India (Zhang and Biswas, 2013; Barnett, 2007; Hall and Lobina, 2006;
 113 Vinning et al., 2005). The lack of understanding and adequate assessment and management of
 114 inherent risks are notable root causes of failure on BOOT projects (Lee and Schaufelberger,
 115 2014; Li and Zou, 2011; Cuttaree, 2008). For example, Aguas del Tunari withdrew from the
 116 US\$2.5 billion, 40-year water utility concession in Cochabamba, Bolivia following violent
 117 protests partly brought about by failure to assess the public's willingness to pay higher tariffs
 118 (Cuttaree, 2008)³.

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

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

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

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136 **Financial risk**

137 The term ‘financial risk’ has variations, as different authors include various factors in their risk
138 lists. Lam and Chow (1999) included counter party, defective products, force majeure, slow
139 progress of works and sovereign risks, while Xenidis and Angelides (2005) included risks such
140 as bankruptcy, prolonged negotiation, lack of guarantees, and rate of return restriction. For this
141 research, the definition of financial risk in BOOT projects proposed by Xenidis and Angelides’s
142 (2005) was adopted, namely events that “negatively impact on the cash flows of the financial
143 plan in a way that endangers [a] project’s viability or limits its profitability” (p. 433). This
144 research considers only risks of an economic nature.

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146 **Research methods**

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

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155 ***Mathematical tool for analysis: Fuzzy set, and FSE***

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

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164 Fuzzy set theory is suitable for qualitative multicriteria analysis because of its capability to
165 resolve or analyze inaccurate and complex decision problems that result from partial and
166 imprecise information that characterize real projects (Boussabaine, 2014; Li and Zou, 2011;
167 Tah and Carr, 2000; Boussabaine and Elhag, 1999). The fuzzy set approach has a rigorous
168 quantitative mathematical theory (Chen and Hang, 1992) that enables systematic processing of
169 qualitative and imprecise information (Khatri et al., 2011). A risk in a fuzzy environment has
170 sets of values that are described by linguistic terms. These qualitative linguistic terms can be

171 expressed numerically by fuzzy sets. Each set is characterized by a membership function
172 ranging between $[0, 1]$, where 0 represents a non-member, and 1 denotes a full member. FSE
173 is one application of the fuzzy multicriteria decision-making techniques considered suitable for
174 this research (Hsiao, 1998).

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

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

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[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’).

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Review of literature and project documentation

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

240 rating panel or test the risks on an actual project.

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

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

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[Insert Table 3]

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273 A preliminary list of 25 financial risks related to BOOT water supply projects in general and
 274 unique to Ghanaian environment was prepared following the literature review and documentary

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

291

292 *Questionnaire survey*

293 *Project background – Nungua Seawater Desalination Plant (NSDP)*

294 A questionnaire survey was conducted on the NSDP⁴ to measure how the project participants
295 perceive the relative significance of the identified risks associated BOOT water supply projects
296 in Table 3. This project is located in Ghana's capital city Accra and is selected because it is the
297 first large-scale water supply project tendered on a long-term BOOT contract in the country.
298 Therefore, the project provides a good example to further our understanding of risks. The
299 NSDP project is a 25-year water purchase agreement between Ghana Water Company Limited
300 (GWCL) and Befesa Desalination Development Ghana Ltd. (Befesa-Ghana: a consortium
301 between Abengoa Water and Daye Water Investment). The NSDP project was finalized
302 financially in November 2012 with a US\$88.7 million 12-year loan from the Standard Bank of
303 South Africa, while the remaining US\$38.1 million came from stakeholder loan and equity.
304 This arrangement resulted in a debt-to-equity ratio of 70:30 (Global Water Intelligence: GWI,
305 2012). This US\$126.80 million project involves the design, construction, operation and

306 maintenance of a 60,000 m³/day desalination plant with a water rate of US\$1.36/m³. The
307 construction duration of the NSDP project is 24 months. GWCL is the off-taker and is
308 supported by a guarantee from the Ministry of Finance and Economic Planning (GWI, 2012;
309 GWCL and Befesa Ghana, unpublished Water Purchase Agreement on NSDP, 2012).

310

311 *Survey and participants for risk assessment*

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

323

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

333 questionnaire was delivered in person, thereby allowing for clarification of any additional
334 issues respondents might have. The questionnaire was then collected after two weeks.

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[Insert Table 4]

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

360 a fuzzy based analysis on the risk factors was conducted to measure the risk level of the project.

361

362 **[Insert Table 5]**

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364 **Evaluation of survey results and findings**

365

366 *Results obtained from FSE analysis*

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

383

384 **[Insert Fig. 1]**

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

387 The basic risks that affect the project are as follows (refer to Table 5): \mathbf{r}_1 = bankruptcy of
 388 consortium member(s), \mathbf{r}_2 = unfavorable economy of the host country, \mathbf{r}_3 = tariff adjustment
 389 uncertainty, and \mathbf{r}_{18} = unfavorable economy of the country of the main stakeholders. Therefore,
 390 $\boldsymbol{\pi} = \{\mathbf{r}_1, \mathbf{r}_2, \mathbf{r}_3, \dots, \mathbf{r}_{18}\}$. The set of qualitative classes (or linguistic variables) for the evaluation
 391 is as follows: \mathbf{v}_1 = 'not critical' (NC), \mathbf{v}_2 = 'very low criticality' (VLC), \mathbf{v}_3 = 'low criticality'
 392 (LC), \mathbf{v}_4 = 'moderately critical' (MC), \mathbf{v}_5 = 'critical' (C), \mathbf{v}_6 = 'very critical' (VC), and \mathbf{v}_7 =
 393 'extremely critical' (EC). Therefore, $\mathbf{V} = \{\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3, \mathbf{v}_4, \mathbf{v}_5, \mathbf{v}_6, \mathbf{v}_7\}$. These linguistic variables
 394 were used to maximize the extensive knowledge of industry respondents, thereby minimizing

395 subjectivity and vagueness in human perception, and to compute the linguistic variables for the
 396 risk level in the NSDP project.

397

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

399 The membership function set (MF_{r_i}) of each risk can be derived by using fuzzy mathematics
 400 based on the value judgment of the respondents. Given the seven linguistic variables in Step 1,
 401 the membership function set of a particular risk r_i is obtained through Equation (1) (Chan,
 402 2007; Liu et al., 2013) as follows:

$$403 \quad MF_{r_i} = \frac{a_{i1}}{v_1} + \frac{a_{i2}}{v_2} + \dots + \frac{a_{in}}{v_n} = \frac{a_{i1}}{\text{extremelylow}} + \frac{a_{i2}}{\text{verylow}} + \dots + \frac{a_{in}}{\text{extremelyhigh}}, \quad (1)$$

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

$$407 \quad MF_{r_i} = (a_{i1}, a_{i2}, \dots, a_{in}). \quad (2)$$

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

$$410 \quad R = \begin{matrix} MF_{r_1} \\ MF_{r_2} \\ MF_{r_3} \\ MF_{r_4} \\ MF_{r_5} \\ MF_{r_6} \\ MF_{r_7} \\ MF_{r_8} \\ MF_{r_9} \\ MF_{r_{10}} \\ MF_{r_{11}} \\ MF_{r_{12}} \\ MF_{r_{13}} \\ MF_{r_{14}} \\ MF_{r_{15}} \\ MF_{r_{16}} \\ MF_{r_{17}} \\ MF_{r_{18}} \end{matrix} = \begin{matrix} a_{11} & a_{12} & \dots & a_{17} \\ a_{21} & a_{21} & \dots & a_{27} \\ a_{31} & a_{32} & \dots & a_{37} \\ a_{41} & a_{42} & \dots & a_{47} \\ a_{51} & a_{52} & \dots & a_{57} \\ a_{61} & a_{62} & \dots & a_{67} \\ a_{71} & a_{72} & \dots & a_{77} \\ a_{81} & a_{82} & \dots & a_{87} \\ a_{91} & a_{92} & \dots & a_{97} \\ a_{101} & a_{102} & \dots & a_{107} \\ a_{111} & a_{112} & \dots & a_{117} \\ a_{121} & a_{122} & \dots & a_{127} \\ a_{131} & a_{132} & \dots & a_{137} \\ a_{141} & a_{142} & \dots & a_{147} \\ a_{151} & a_{152} & \dots & a_{157} \\ a_{161} & a_{162} & \dots & a_{167} \\ a_{171} & a_{172} & \dots & a_{177} \\ a_{181} & a_{182} & \dots & a_{187} \end{matrix} = \begin{matrix} 0.00 & 0.00 & 0.00 & 0.00 & 0.33 & 0.33 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.14 & 0.57 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.14 & 0.14 & 0.43 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.14 & 0.29 & 0.29 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.57 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.43 & 0.57 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.67 & 0.17 & 0.17 \\ 0.00 & 0.00 & 0.00 & 0.17 & 0.50 & 0.00 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.71 & 0.14 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.29 & 0.57 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.40 & 0.20 & 0.00 & 0.40 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.14 & 0.29 \\ 0.00 & 0.00 & 0.17 & 0.17 & 0.33 & 0.00 & 0.33 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.57 & 0.29 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.14 & 0.57 & 0.29 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.43 & 0.14 & 0.29 & 0.14 \\ 0.00 & 0.00 & 0.00 & 0.29 & 0.43 & 0.14 & 0.14 \end{matrix} \quad (3)$$

411

412 After deriving the membership function set of each risk in Equation (3), an index suggested by
 413 Chen (1998) was used to compute the ‘mean criticality’ (Z_i) of each risk to determine its rank

414 and degree of criticality to the project. Criticality index of each risk is obtained by
 415 defuzzifying its membership function set using Equation (4). The reason for using Equation
 416 (4) is that the risk criticality rating has drawn on the expert judgment of the respondents using
 417 linguistic values (which can be considered an ordinal measurement system) and is
 418 representative of the risk assessments of the respondents.

419

$$420 \quad Z_i = a_{i1}k_1 + a_{i2}k_2 + \dots + a_{in}k_n = \sum_{j=1}^n a_{ij}k_j \quad (4)$$

421 where

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

424 a_{ij} represents the degree of membership, and

425 k_i represents a variable of varying impact level of a risk. The seven linguistic grades in
 426 Step 1 ($v_1, v_2, v_3, v_4, v_5, v_6,$ and v_7) with the corresponding numeric grades (1, 2, 3, 4, 5, 6,
 427 and 7, respectively) assigned to them described the impact levels of the risks. The numeric
 428 grades were used to defuzzify the membership function sets of the risk factors.

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

435

436 **[Insert Table 6]**

437

438 *Step 3: Compute the weighting functions of the risks*

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

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

Therefore, the normalized weighting function set is

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

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

450

451

[Insert Fig. 2]

452

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:

$$R \circ W = D, \quad (7)$$

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

where d_k is the membership function of the denominator v_k with respect to the fuzzy evaluation vector $D = (d_1, d_2, \dots, d_7)$. 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):

$$d_k = \min \left\{ 1, \sum_{i=1}^{\circ} w_i a_{ij} \right\}, \quad j = 1, 2, \dots, n. \quad (9)$$

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 $M(\bullet, +)$; thus,

$$d_k = \sum_{i=1}^{\circ} w_i a_{ij}, \quad j = 1, 2, \dots, n. \quad (10)$$

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

471
 472 Therefore, by using Equation (8), the result of the fuzzy evaluation vector of the project risk
 473 level becomes

$$474 \quad D = \frac{0.00}{\text{extremely low}} + \frac{0.00}{\text{very low}} + \frac{0.01}{\text{low}} + \frac{0.19}{\text{moderate}} + \frac{0.36}{\text{high}} + \frac{0.25}{\text{very high}} + \frac{0.19}{\text{extremely high}} \quad (11)$$

475 $= (0.00, 0.00, 0.01, 0.19, 0.36, 0.25, 0.19).$

476
 477 *Step 5: Defuzzify the fuzzy vector of the project risk level*

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

$$482 \quad Z_{\text{FRL}} = \sum_{k=1}^{\circ} d_k \cdot k = 0.00 \times 1 + 0.00 \times 2 + 0.01 \times 3 + 0.19 \times 4 + 0.36 \times 5 + 0.25 \times 6 + 0.19 \times 7 = 5.4312 \quad (12)$$

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

488
 489 **Reliability analysis**

490 Table 7 provides important information termed "project risk level (score) if risk item is deleted."
 491 This follows measurement scales' reliability analysis (see Pallant, 2005). This information
 492 measures the effect or contribution of each risk factor to the overall risk score (index) of the
 493 case project. The risk scores are the scores of the overall risk level of the NSDP project if the
 494 corresponding risk is removed from the calculation of the fuzzy model. Therefore, the risk
 495 scores (which depict the project risk level) are based on 17 risk factors, excluding the
 496 corresponding risk factor. By comparing these risk level scores with the overall risk level score
 497 (5.43) obtained in Equation (12), any risk factor that effectively contributes to the FRL of the
 498 NSDP project should have a corresponding score ≤ 5.43 . By contrast, a risk factor that does
 499 not contribute will have a risk level score > 5.43 . However, this condition is not violated; thus,
 500 each risk factor effectively contributes to the financial risk level of the NSDP project. None of

501 the risks should also be excluded from the 18-factor risk list. Also, Table 7 implies that the
502 items in our measurement scale measured the same underlying construct and that the scale is
503 reliable and has a good internal consistency.

504

505 **[Insert Table 7]**

506

507 **5. Discussion**

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

522

523 *The bankruptcy of consortium member(s)* is assessed as the most critical risk with a 'very
524 critical' rating (Table 6). This risk informs public clients that the progress of a project can be
525 jeopardized in case the concessionaire files for bankruptcy. This information is critical because
526 a possible bankruptcy risk may or may not necessarily relate to the project in question but to
527 other business operations of the stakeholder(s) (Xenidis and Angelides, 2005). For example, in
528 the troubled Tampa Bay Seawater Desalination Plant, the Covanta Tampa Construction was
529 awarded a construction contract and a 30-year concession to operate and maintain the facility.
530 Vinning et al. (2005) explained that because of the poor and mistrustful relationship between
531 Covanta and Tampa Bay Water, the former filed for bankruptcy in October 2003; the primary
532 reasons include the energy crisis in California, which affected the cash flow of Covanta (Barnett,
533 2007), and to stop Tampa Water from terminating the partnership and replacing Covanta
534 (Vinning et al., 2005). Ultimately, the risk adversely affected the project in terms of cost and

535 time because Tampa Water had to find another firm to replace Covanta and to address the
536 treatment problems of the plant (Wall, 2013; Barnett, 2007).

537

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

551

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

565

566 *The rate of return restriction risk (profitability)* reflects the decision of the current or future
567 government to restrict or impose a cap on the rate of return of the investment of the project
568 (e.g., if the returns of the investors are deemed excessive) (Xenidis and Angelides, 2005). Being

569 the first capital-intensive BOOT water supply project in Ghana, the respondents are concerned
570 that a future government may retain a rate of return for the investment. Experience shows that
571 rate of return restrictions frequently occur in BOOT projects; for example, foreign investors in
572 China have raised concerns regarding the 15% cap of the authorities on the rate of return of
573 private investment projects (Lee and Schaufelberger, 2014; Wang et al., 2000). Therefore,
574 imposing caps on the rates of return of projects has immense consequences, as reflected by the
575 ‘very critical’ score of the risk. These consequences include a reduction in the viability of a
576 BOOT project because the cap limits the capability of investors to balance project risks with
577 corresponding returns (Wang et al., 2000), as well as proves difficult in attracting investors or
578 finances for infrastructure projects, as experienced in the Laibin B Power Plant in China (Lee
579 and Schaufelberger, 2014).

580

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

602

603 The proposed fuzzy methodology provides useful implications for practitioners. This

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

613

614 **Limitations and further work**

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

631

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

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

645

646 **Conclusions and significance**

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

658

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

669

670 The results indicate that the FSE method can be used to evaluate and prioritize risks in BOOT
671 or PPP projects. The method does not always require a statistically significant sample size, and

672 improves the accuracy of assessment results given its ability to effectively handle the
 673 subjectivity of experts. Because the input data in FSE analysis are based on experts' perceived
 674 judgements makes it suitable for the early phases of BOOT / PPP projects to determine
 675 significant risks that require the attention of and detailed analysis by project managers.

676

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

699

700 Notes:

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

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

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

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

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

715

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Tables

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

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

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

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

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

Financial risks	NSDP*	Selected references									No.	
		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]		
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

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Table 4. Designation of members of the risk assessment team

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

*Local partner to the NSDP project

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

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

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Table 6. Evaluation results of the financial risks

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

*Refer to Table 4 for definition of terms and their ranges.

**Where two or more factors scored the same mean, the highest ranking is assigned to the one with the least standard deviation.

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Table 7. Checking reliability of the risk assessment result

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

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